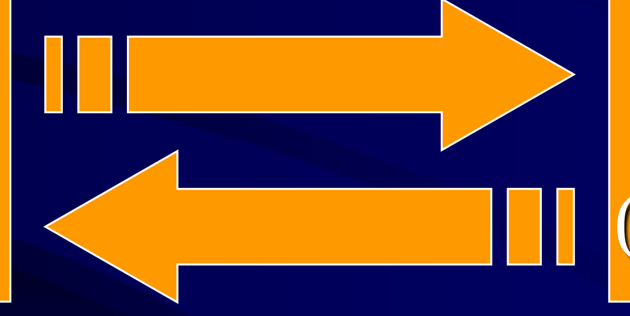
Automation & Control

The Process

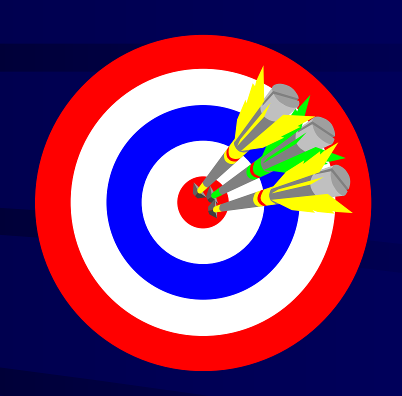
Any process consist of :-

(1) Application

(2) Control System

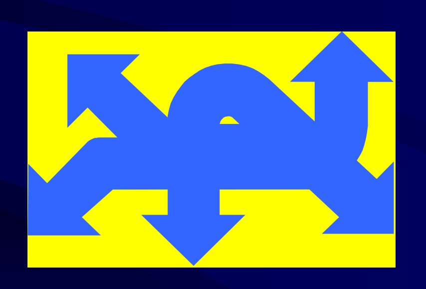


Automation Objectives



Directly

Reducing cost
Improving quality



Indirectly

Improving working condition

Automatic Control

Control System is divided into



Processing section has the task to produce predetermined responses (in the form of outputs) as a result of information by the input signal measurements

Inputs

Input signals are provided by transducers / detectors that convert physical quantities into electrical signals. Depending on transducer used, the information detected can discontinues (binary) or continuous (analog) representation of the input quantity

Transducers	*Measured Quantity*	*Output Quantity*
Switch	Movement / Position	Binary Voltage
Limit Switch	Movement / Position	Binary Voltage
Thermostat	Temperature	Varying Voltage
Thermocouple	Temperature	Varying Voltage
Thermistor	Temperature	Varying Resistance
Strain Gauge	Pressure / Movement	Varying Resistance
Photo Cell	Light	Varying Voltage
Proximity Cell	Presence of Objects	Varying Resistance

Outputs

Output devices (like relays, pumps, motors..) are tools used by a control system to alter certain key element or quantities within the process.they are also transducers but contrary signals from the control system into other necessary. There are also discontinuous (binary) or continuous (analog) devices

Output device	*Quantity Produced*	*Input*
Motor	Rational motion	Electrical
Pump	Rational motion + product displacement	Electrical
Piston	Linear motion / pressure	Hydraulic / pneumatic
Solenoid	Linear motion / pressure	Electrical
Heater	Heat	Electrical
Valve	Orifice variation	Electrical/Hydraulic/pneumatic
Relay	Elec. Switching / limited physical movement	Electrical

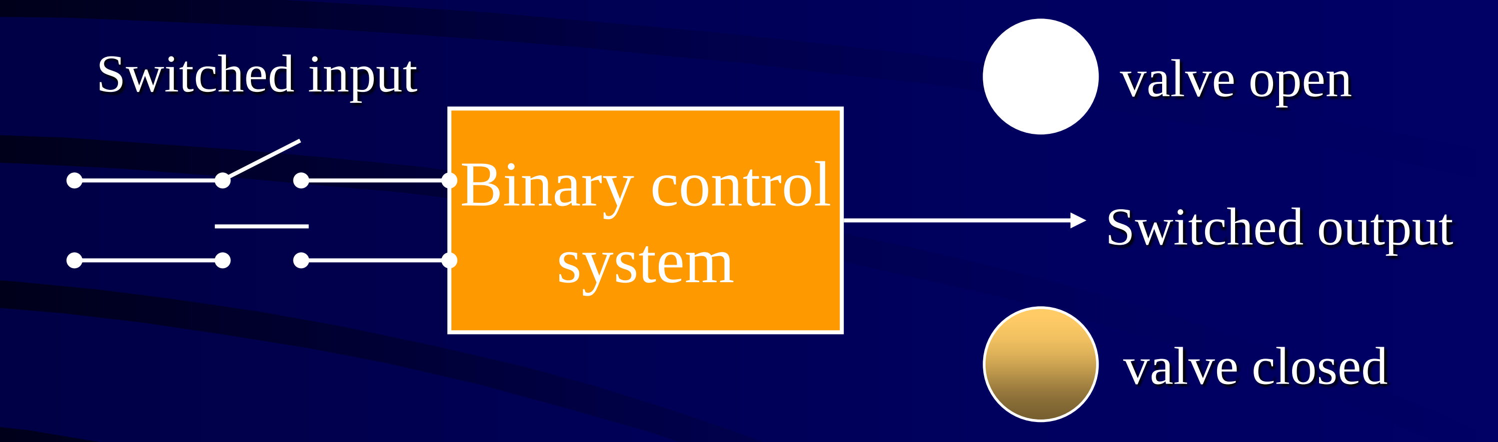
Processing Section

This corresponds to the operations required to keep process "in control" in conjunction obtained from input readings, producing resultant output action.input causes output action due to a control plan which can either hardwired or programmable

System	Type	Hard	program
Relay	Digital	🗐	🗄
Electrical logic	Digital	🗐	🗄
Pneumatic logic	Digital	🗐	🗄
Analog logic	Digital	🗐	🗄
Computers	Digital/analog	🗄	🗐
PLCs	Digital	🗄	🗐

Digital Systems

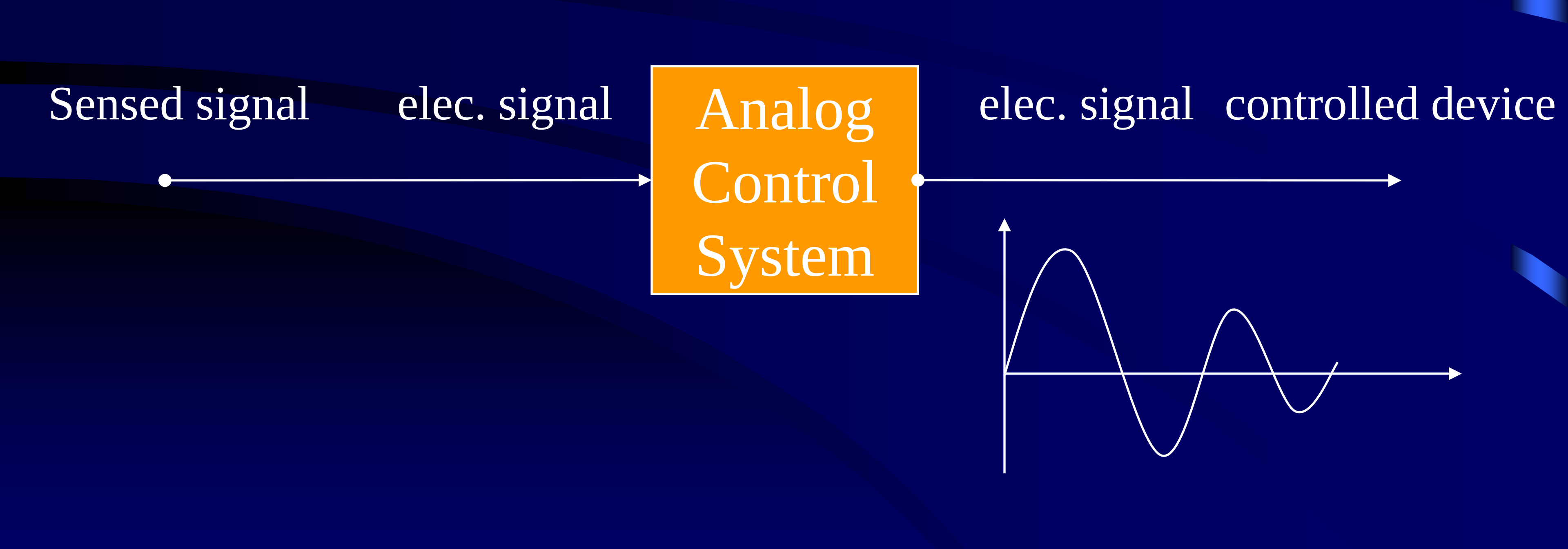
Discontinuous or on / off control is most common system, since many machines and processes consist of units controlled by a larger number of simple operation or sequence steps



Many devices produce or respond to digital signals,where there are only one of tow conditions

Analog Systems

Continuous or analog control is related to the varying quantities such as temperature, speed, … change gradually and continuously across an infinite of values.



Control Strategies

Open Loop

Requirements → Control plan → Action → Plant system → Outcome

Disturbance

Feedforward

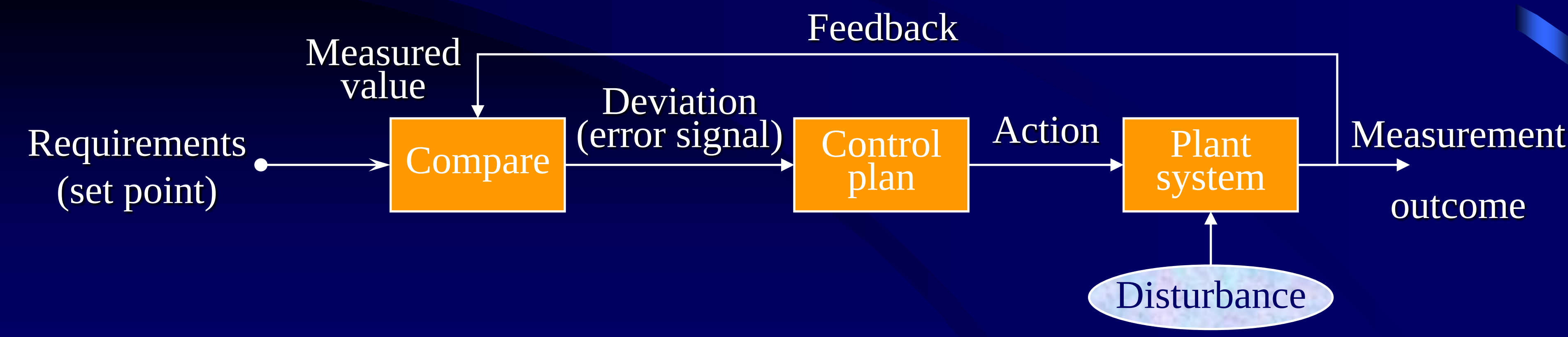
Requirements → Control plan → Action → Plant system → Outcome

Disturbance

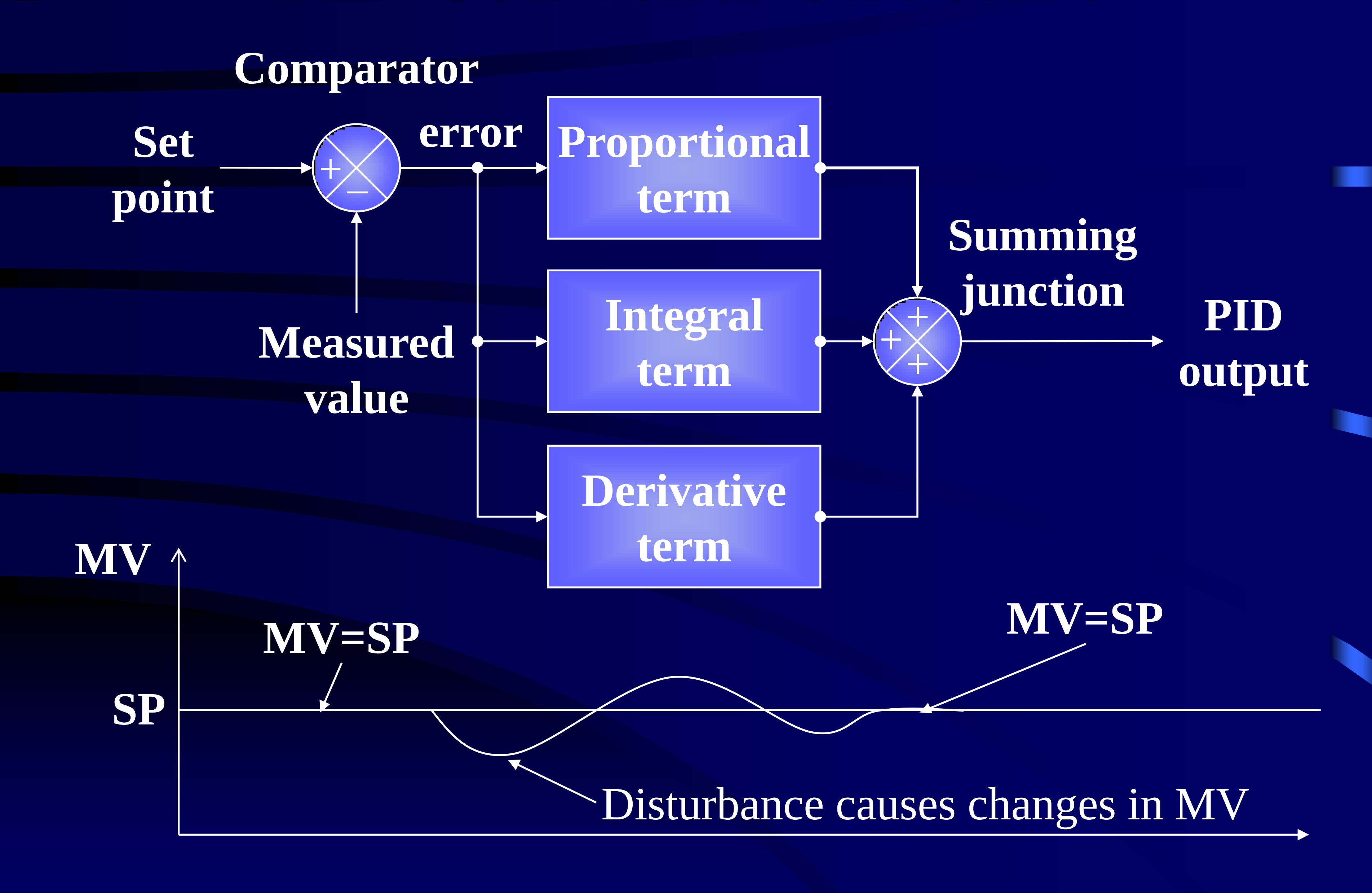
Measurements of disturbances

Modification to plan taking account of disturbance

Closed Loop



PID Controller Structure

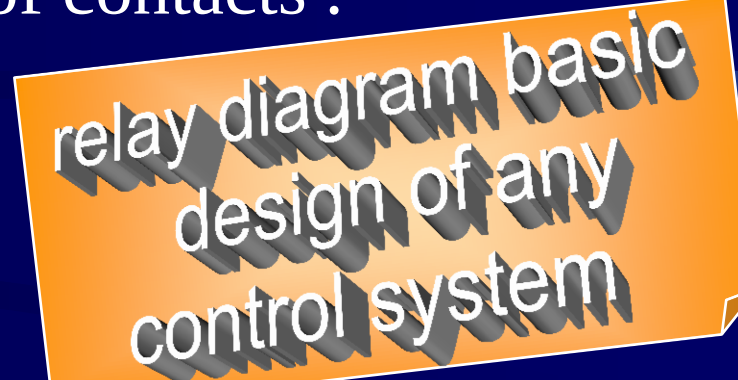


Industrial Processes

Continuous	Batch	Discrete
I/P is introduced and runs continuously producing an O/P process may run for long period of time typically minutes hours or event weeks. (e.g steel sheet Production)	A batch process uses a set quantity of I/P material & performs process operations on this material .producing a specific quantity of finished O/P product that will undergo further stages of processing. (e.g food&beverage production)	in this type of process an individual item under goes various operations before being produced in a final form alternatively, several components may be combined Within the process. to emerge as one unit

Relay Control

- Group of relays with large number of contacts .
- space required .
- Fixed application,
- Simple control tasks.
- Difficult expansion and/ or modification.
- Slow action.





Relays continue to be used as output device another types of control systems, being ideal for the conversion of small signals to higher current / voltage driving signal

Electronic Control

Linear integrated circuits

- 🕮Handie analog signals.
- 🕮Important component”op-amp”.
- 🕮Involve complex math (differentiation,integration,…).
- 🕮Bases of loop controls.
- 🕮Limited fine tuning of feedback systems.

Digital integrated circuits

- ✐Deal exclusively with binary signals.
- ✐Process information through logic gates.
- ✐Various logic families (CMOS, TTL, …).
- ✐Logic symbols & Boolean algebra…design&analysis.
- ✐Large ICs with enormous number of gates.
- ✐Heard of microprocessors.

Sequential Control

- basis of computer operation.
- digital systems that have outputs dependent on previous system state



Programmable Computing Control Systems

Input Data

Data memory

Firmware

Program

Output Data

Programmable logic control

PLC a Process Control Computer System

Key Board
Light Pen
Mouse



Monitor
Printer
Plotter

Motion Sensor
Sound Sensor
Heat Sensor
Light Sensor

Process Control
Computer System

Motor
Solenoid
Heater
Light

Definition & Advantages

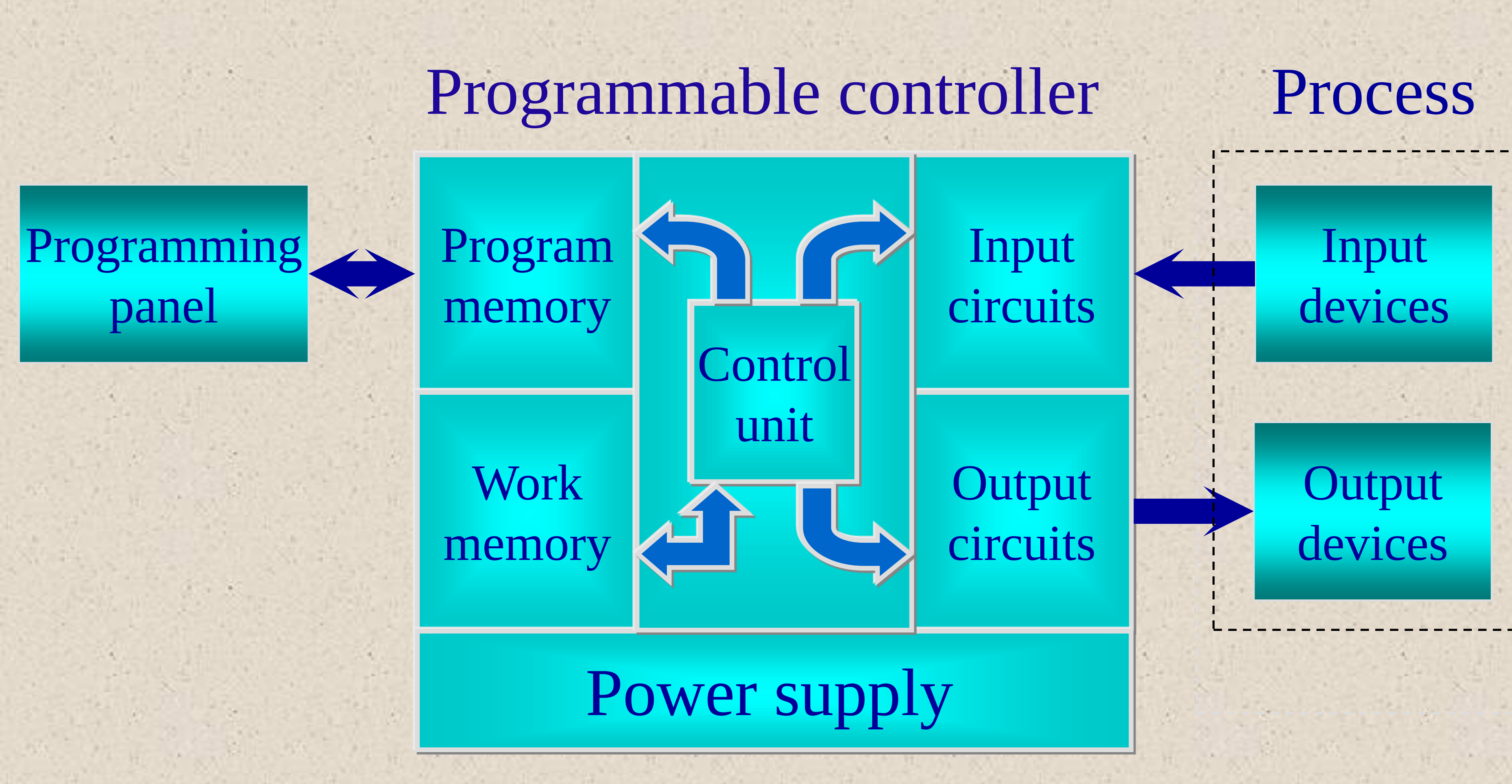
A **PLC** is user-friendly, microprocessor-based, specialized computer that carries out control schemes of many types and levels of complexity. It can be programmed, controlled and operated by person unskilled in computers

- rugged-noise immune equipment
- modular-easy installation/replacement
- standard I/O connections & signal levels
- simple programming.
- compact sizes.
- cost competitive

Comparison with Other Control Systems

C\Cs	Relay systems	Computers	PLC systems
Price Per Function	Fairly Low	High	Low
Physical Size	Bulky	Fairly Compact	Very Compact
Operating Speed	Slow	Fairly Fast	Fast
Noise Immunity	Excellent	Fairly Good	Good
Installation	Time Consuming in All Phases	Time Consuming in Programming	Easy in All Phases
Complex Operation	None	Yes	Yes
Ease of Changes	Very Difficult	Quite Simple	Very Simple
Easy of Maintenance	Poor-large No. Of Contacts	Poor-several Custom Boards	Good-few Standard Cards

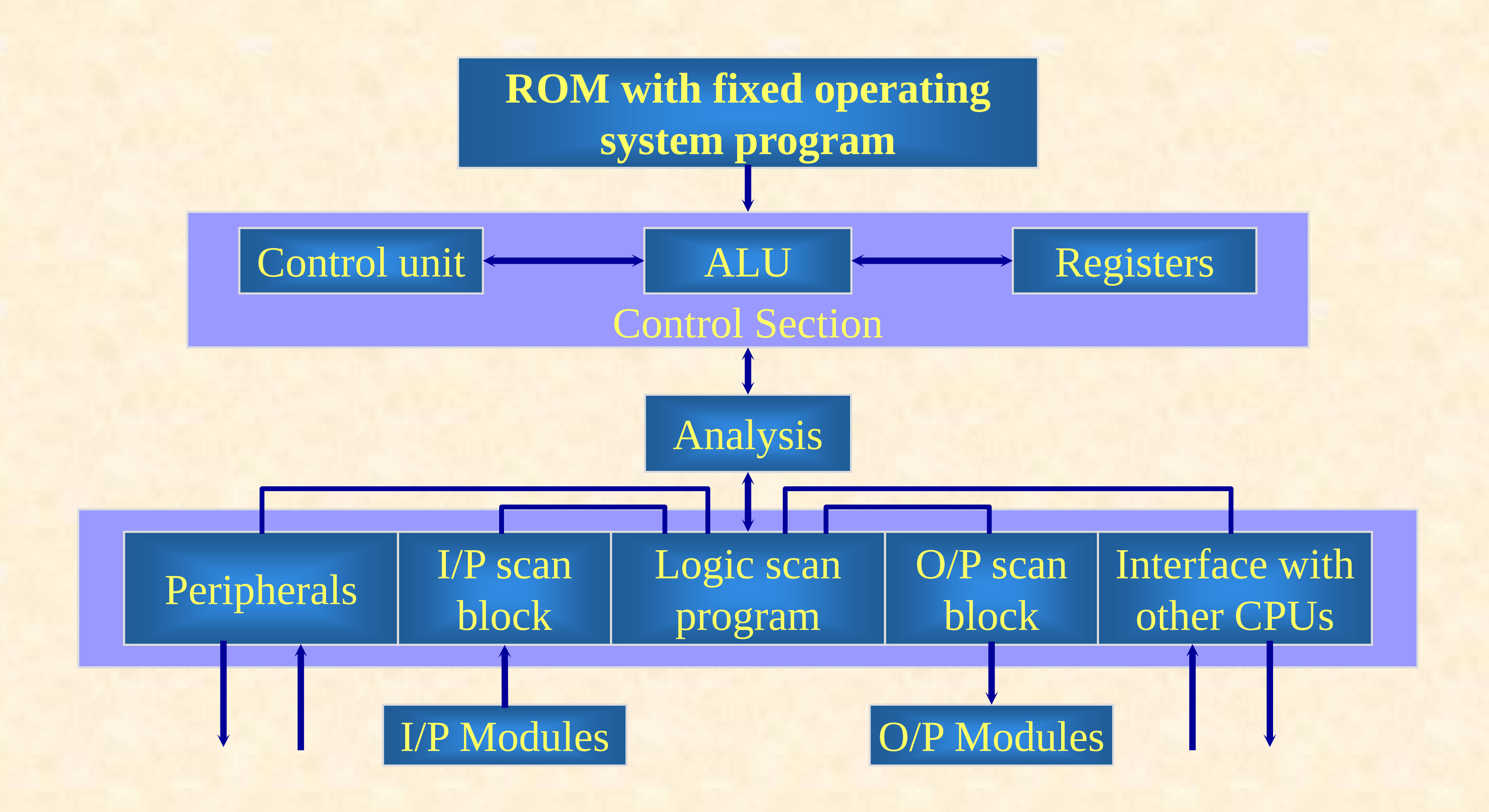
Structure


Programmable controller
Process
Programming panel
Program memory
Work memory
Control unit
Input circuits
Output circuits
Input devices
Output devices
Power supply

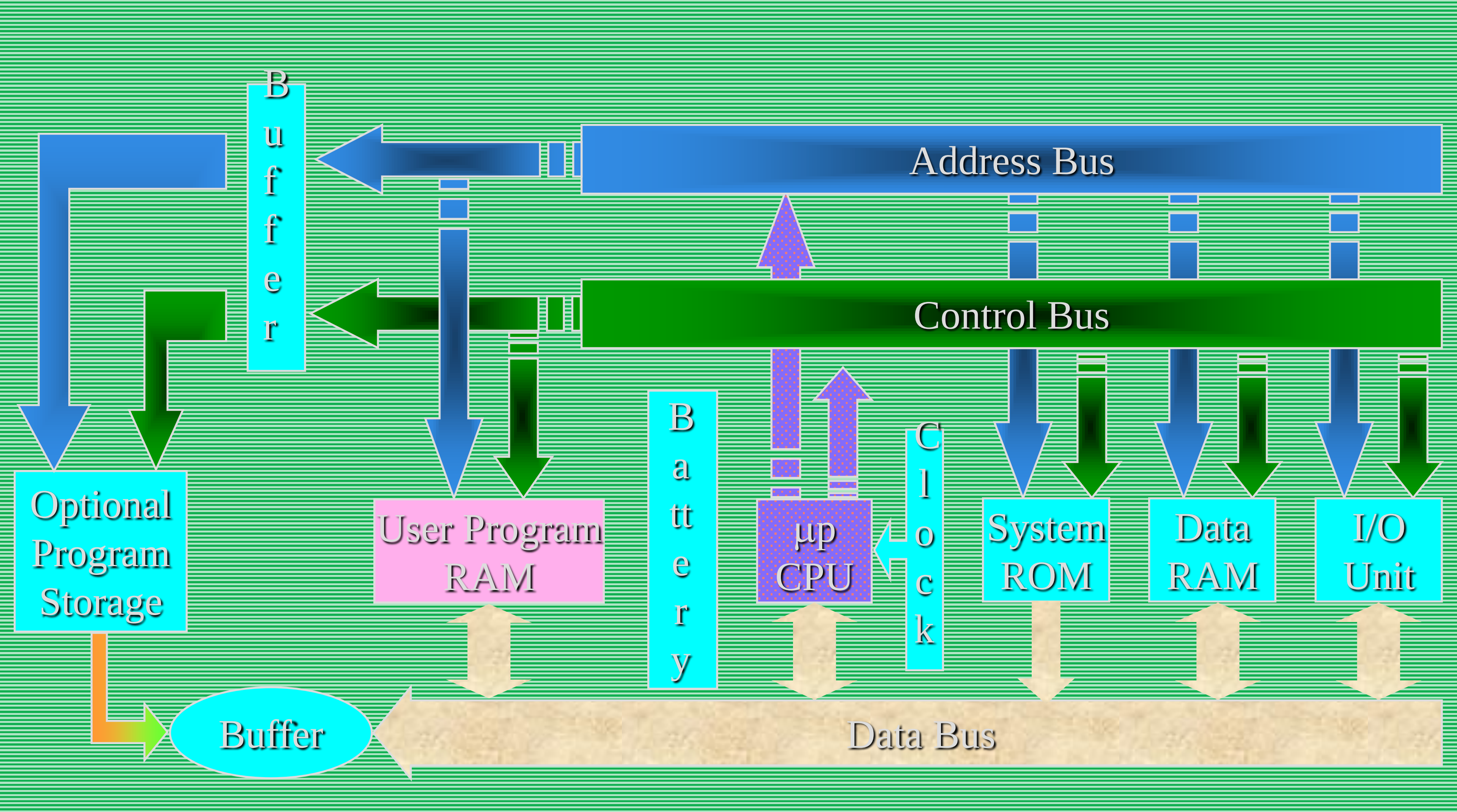
Central Processing Unit “CPU”(1)

- The CPU controls and supervises all operation within PLC, carrying out programmed instructions stored in the memory.
- An internal communications highway or bus system carries information to and from CPU, memory and I/O units, under CPU control.
- The CPU is supplied with a clock frequency by a quartz crystal or RC oscillator with speed depending on the microprocessor type.
- The clock determines the operating speed of the PLC and provides timing/synchronization of all system elements.

Central Processing Unit "CPU"(2)



Central processing unit "CPU" (3)



System memory

- Can be subdivided into two types :

  Executive Memory and *Scratchpad Memory*.

- *Executive memory* contains the executive operating system .Such system is provided by PLC manufacturer and rarely changed, so it is loaded on a PROM.

- It provides the translation between the high level programming language and the binary machine language,scans PLC to update system status and reads inputs and updates outputs.

- During administration of these functions, the executive often needs an area of memory to store data temporarily: the memory is called *Scratchpad Memory*, it is a RAM which is not accessible by the user

I/O Status Memory

- It is a portion of RAM dedicated for storage of current I/O status.
- As the executive program requires I/O status update, the I/O status memory can be considered as part of system memory

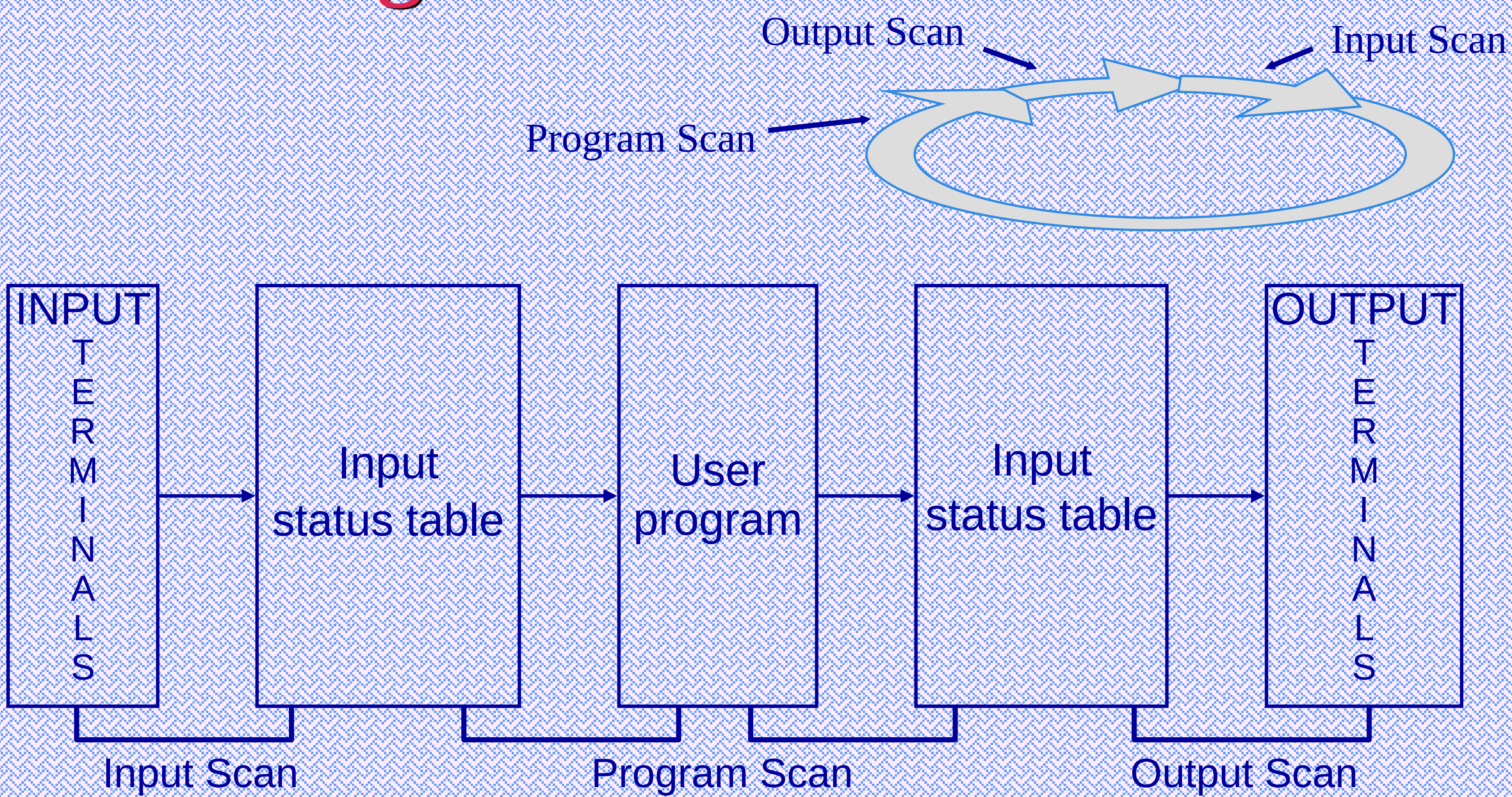
Application Memory

- It can be subdivided into two types :

  Data memory & User memory.

- **Data memory** holds generally the preset values (like timers,…).
- **User memory** is the most accessible by the user where all program sequence and specific functions are handled. It is scanned by CPU for instructions when it is directed for scan by the executive.

I/O scanning



Output terminals are read and input status table is updated accordingly.

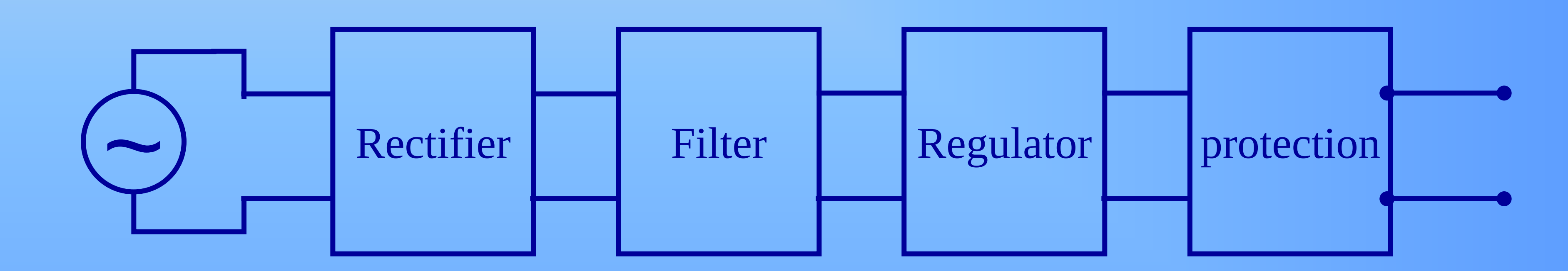
During program scan data in I/P table is applied to user program, program is executed and O/P table is updated accordingly.

Data associated with O/P status table is transferred to O/P terminal.

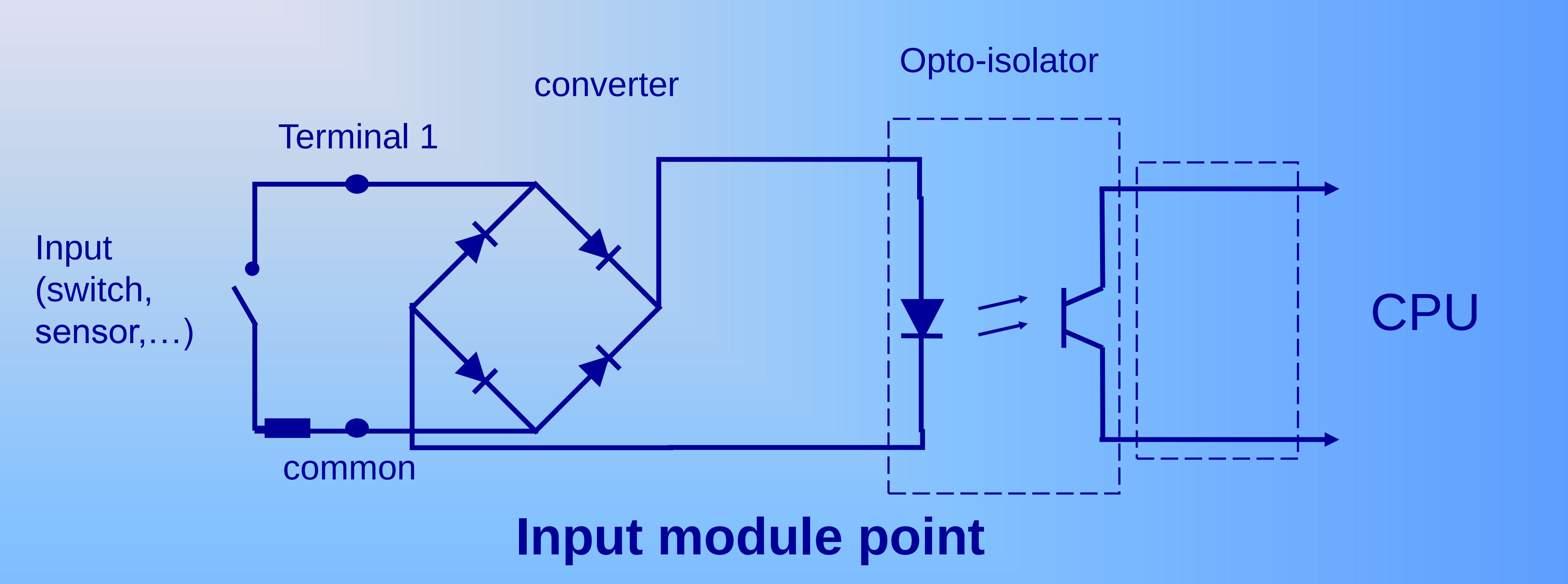
Power Supply

•PLCs internal circuitry operates at +/-5V DC.

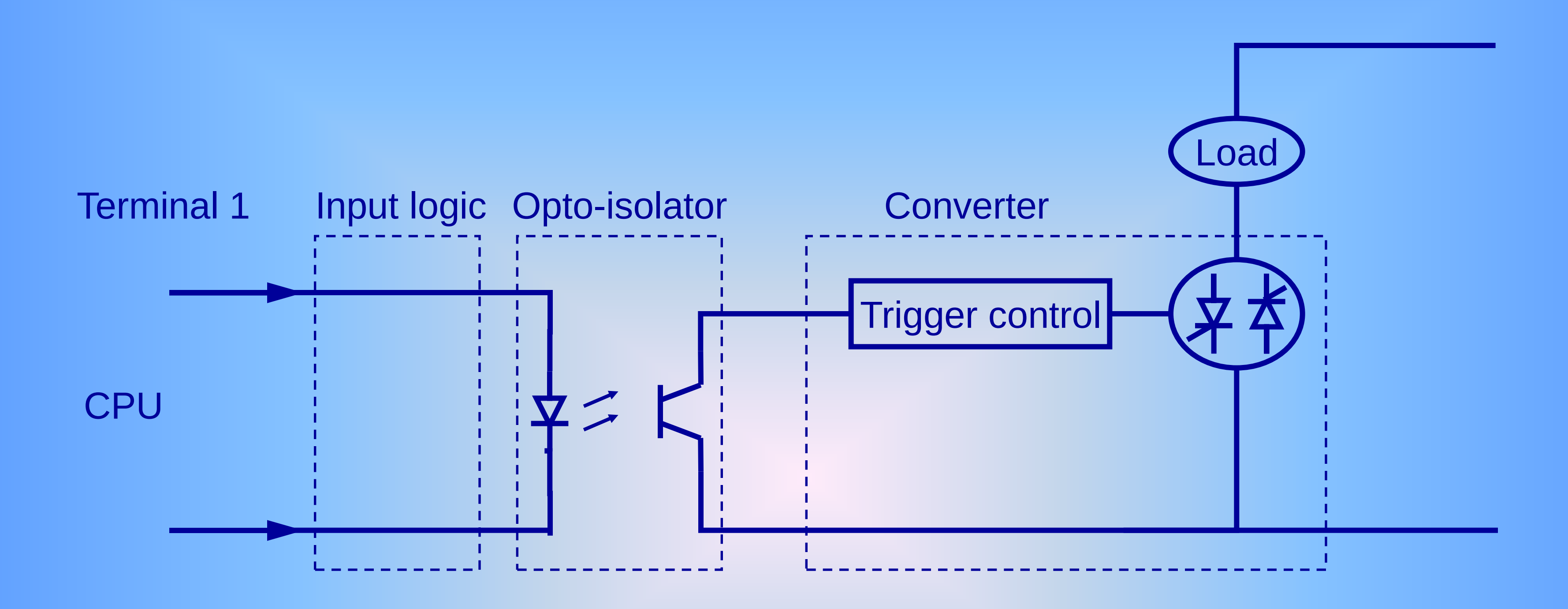
•Whether the available supply is AC or DC, a power supply is required to condition, regulate, ... this supply to the adequate need of the circuitry.



Discrete Input

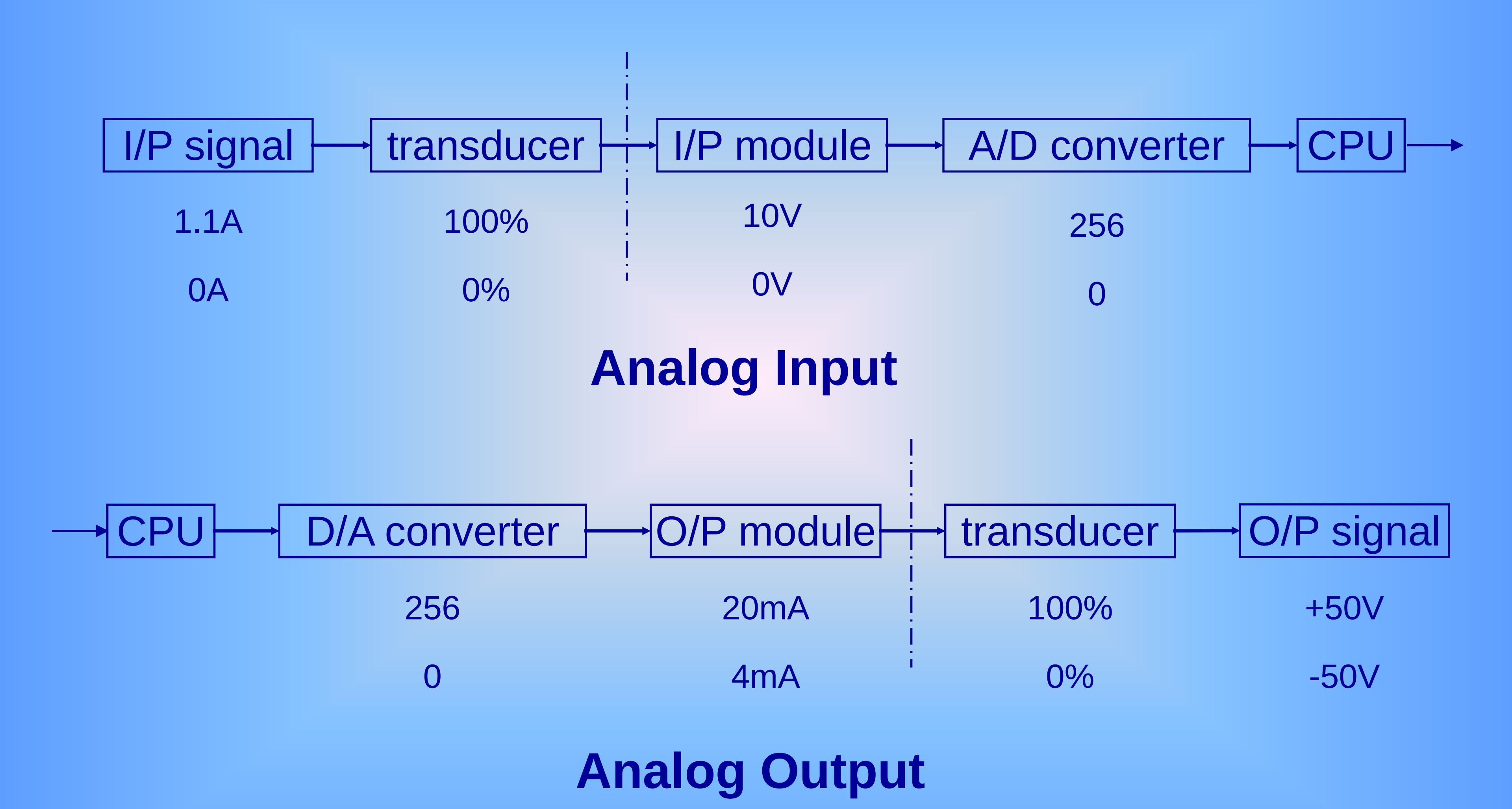


Discrete Output



Output module point

Analog I/O



I/P signal
transducer
I/P module
A/D converter
CPU
1.1A
0A
100%
0%
10V
0V
256
0
Analog Input
CPU
D/A converter
O/P module
transducer
O/P signal
256
0
20mA
4mA
100%
0%
+50V
-50V
Analog Output

I/O Modules

- PLCs operate at 5V DC to 15V DC, whilst process signals can be much greater or of different levels.
- The I/O units from the interface between the microelectronics of PLC and the real world outside.
- These units provide all necessary signal conditioning and isolation functions.
- I/O modules are available (Digital, analog) with all different process signals which allow PLC to be directly connected to process.

Special Modules

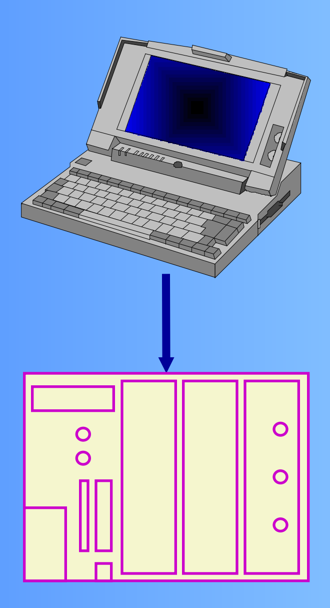
- These modules are intelligent ones which perform certain tasks independent of the CPU.
- The use of such modules in process control is Known as distributed processing.
- Such modules are dedicated computers that perform preset calculations on data received from detectors or other devices connected to it.
- PLC CPU is thus freed to handle larger control functions.

Housing

- Small PLCs are build of individual printed circuit cards within single compact unit
- small PLCs are constructed modular basis with function modules slotted into the back plane connectors of the mounting rack
- modular systems housing or mounting racks are equipped with buses to exchange all information required to run the system: data, control, address,….

Communication - Point to Point

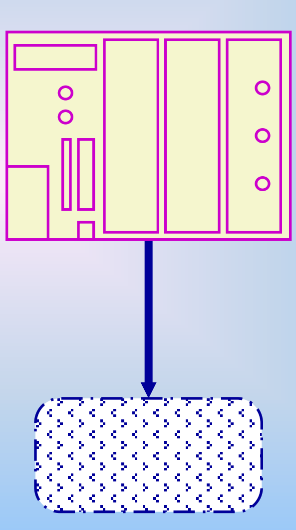
Between two intelligent devices -CPUs



Links:

•PLC w/ programming terminal.

•PLC w/ Man Machine Interface.



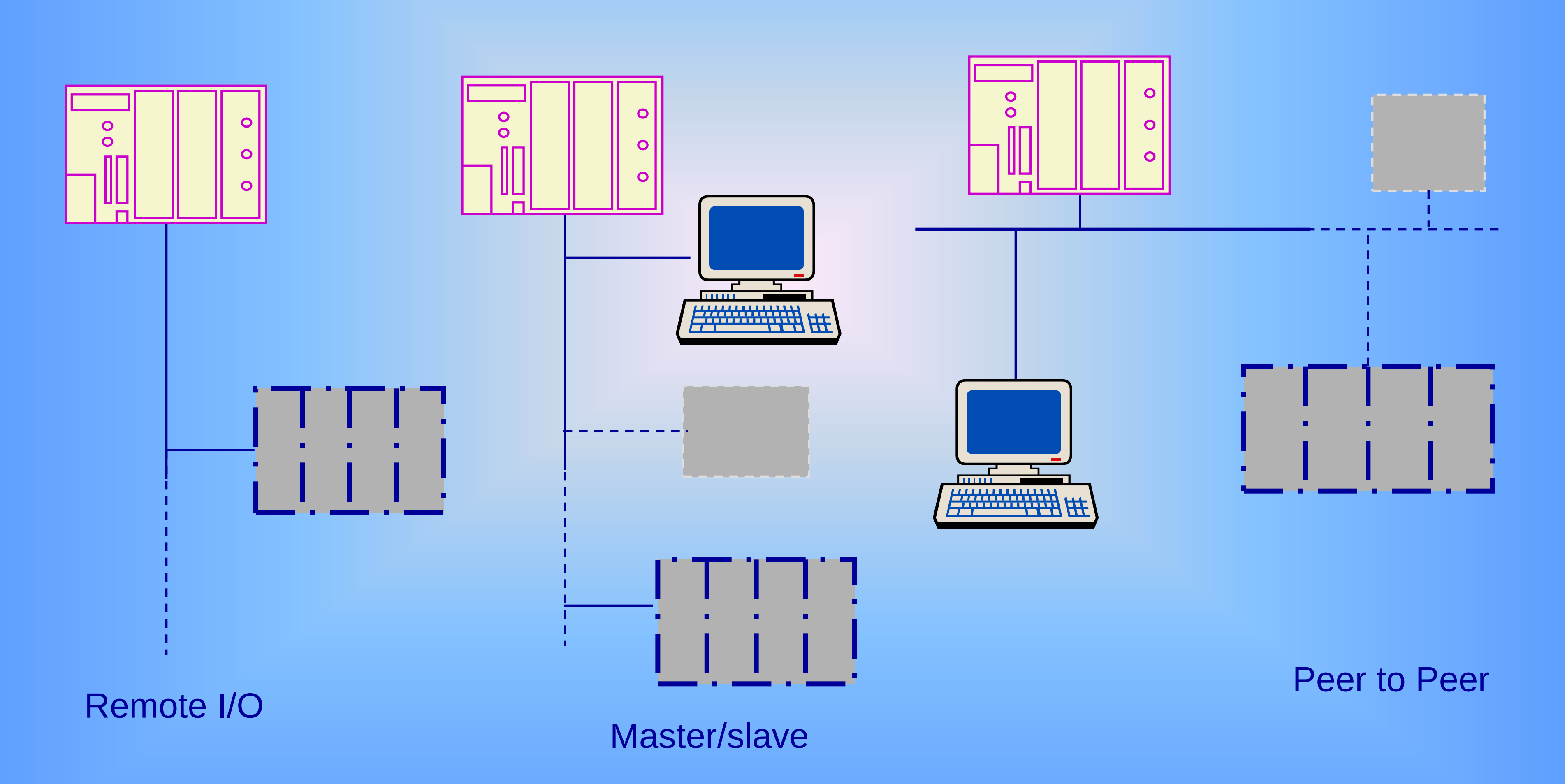
Links:

•PLC w/ other PLC.

•PLC w/ any intelligent device.

Communication - Networking

Between intelligent devices - CPUs & others



Programming Equipment

- Allowing writing, editing and monitoring a program as well as performing various diagnostic procedures.
- Three types of programming tools are in common use:

  1. Hand held programmer
  2. Portable programming terminal
  3. S/W to run on PC
- the third type is commonly used and have larger capabilities.

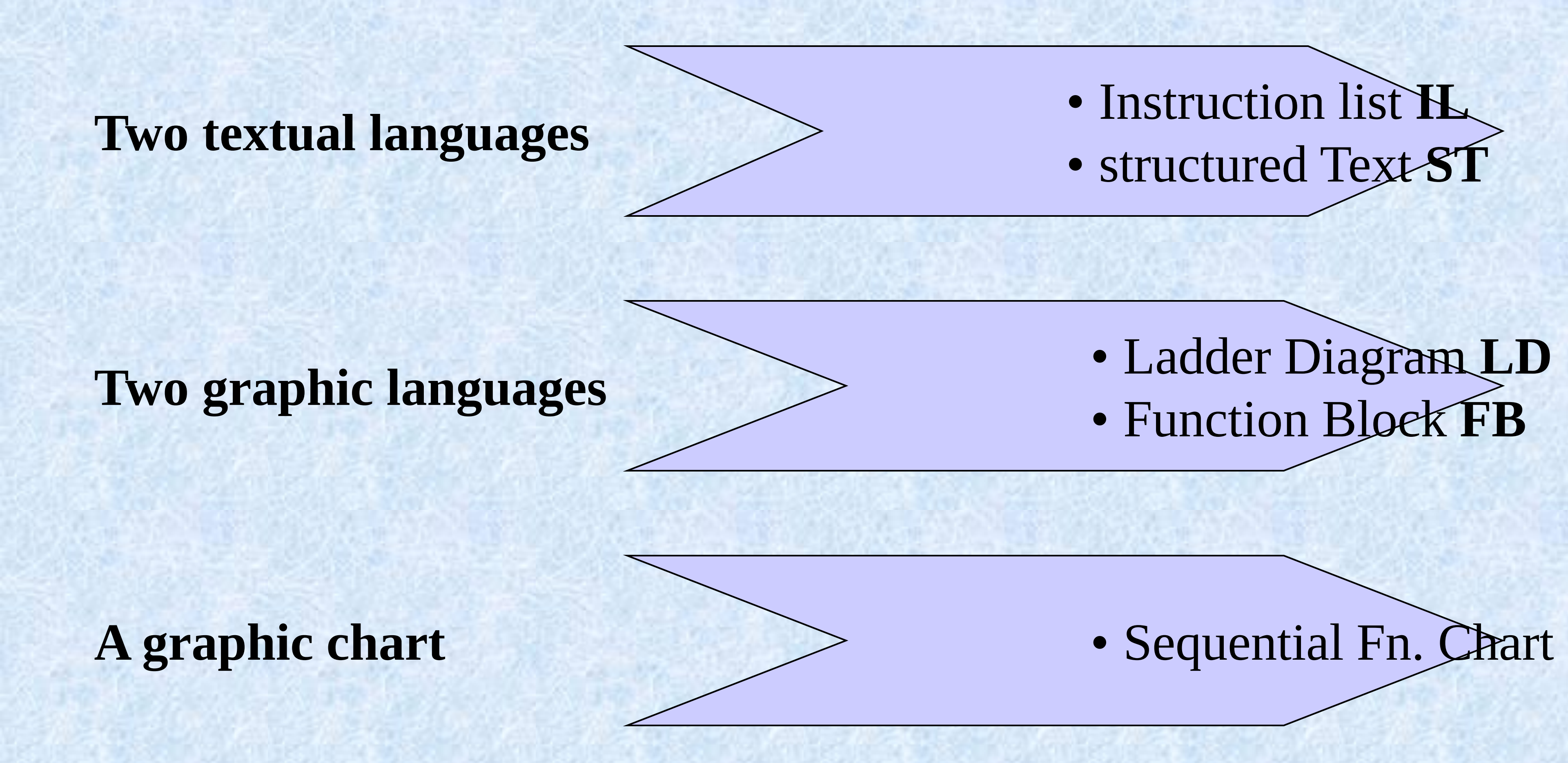

Programming
Languages

IEC 1131

- 1979 :The International Electromechanical Commission assigned the research committee 65A to define a PLC standard.
- Objective :to meet the increasing complexity requirements of control and monitoring systems and the large number of PLCs which are incompatible with each other.
- Its contents :
  - IEC1131-1 :General information (1992).
  - IEC1131-2 :Specifications & equipment testing (1992).
  - IEC1131-3 : Programming languages (1993)
  - IEC1131-4 : Recommendation to the user.
  - IEC1131-5 :Message handling functions specifications.

IEC 1131-3

This standard describes:-



Instruction List (IL)

- Series of instructions, each one must start on a new line.
- One instruction = operator + one or more operations separated by commas.
- Function Blocks lunched using a special operator.

Label	Operator	Operation	Comment
Run:	**LD**	**%IX1**	(*pushbutton*)
	ANDN	**%MX5**	
	ST	**%QX2**	(*run*)

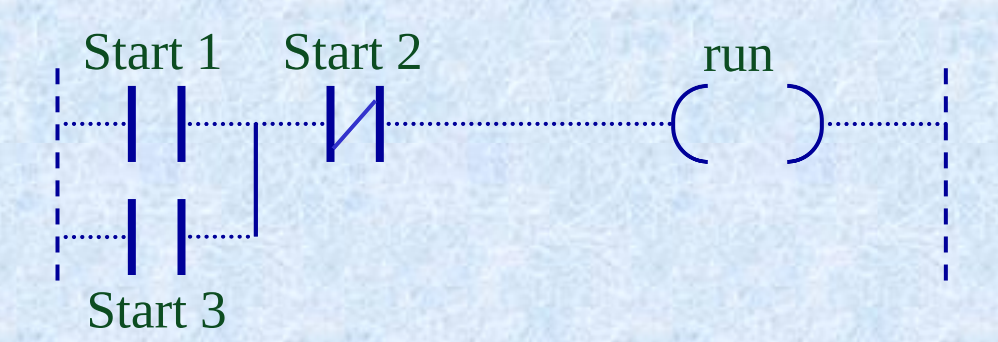
Structured Text (ST)

- Syntax similar to that of Pascal enabling a description of complex algorithmic structure
- succession of statements for assigning variables, controlling functions and function blocks, using operators, repetition, conditional executions.
- Function blocks launched using a special operator.

```
J:=1
WHILE J<=100 & X1<>X2DO
J:=J+2
END_WHILE
```

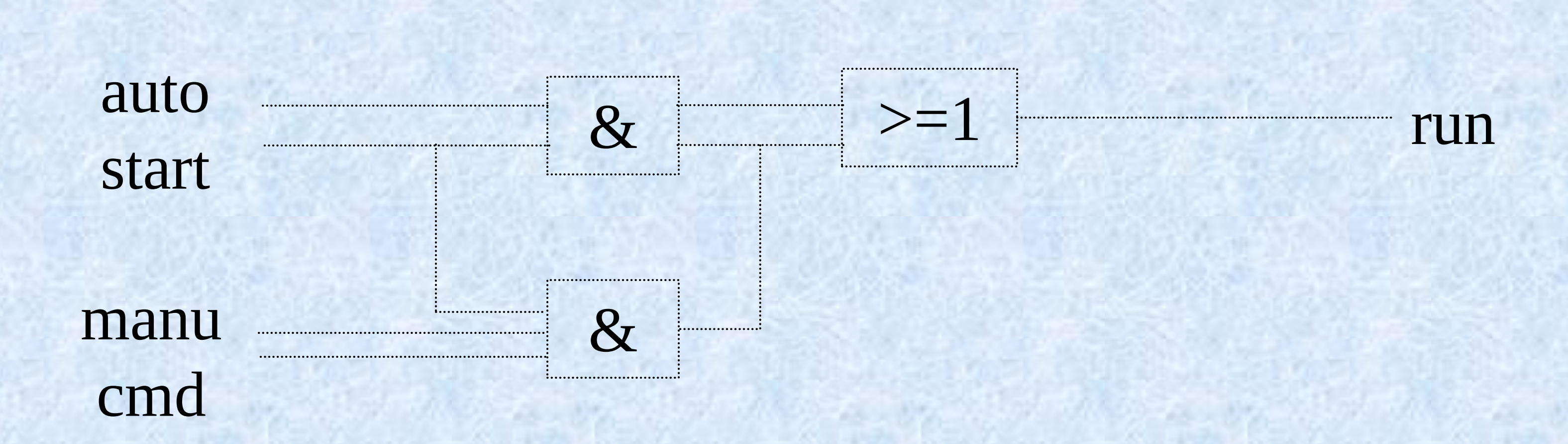
Ladder Diagram (LD)

- Graphic elements organized in networks connected by power supply rails.
- Elements used :contacts, coil, functions, function blocks control elements (jump, return, etc.)



Function Block Diagram (FBD)

- Representation of functions by blocks linked to each other.
- Network evaluation :from the O/P of a function block to the I/P of the connected function block.



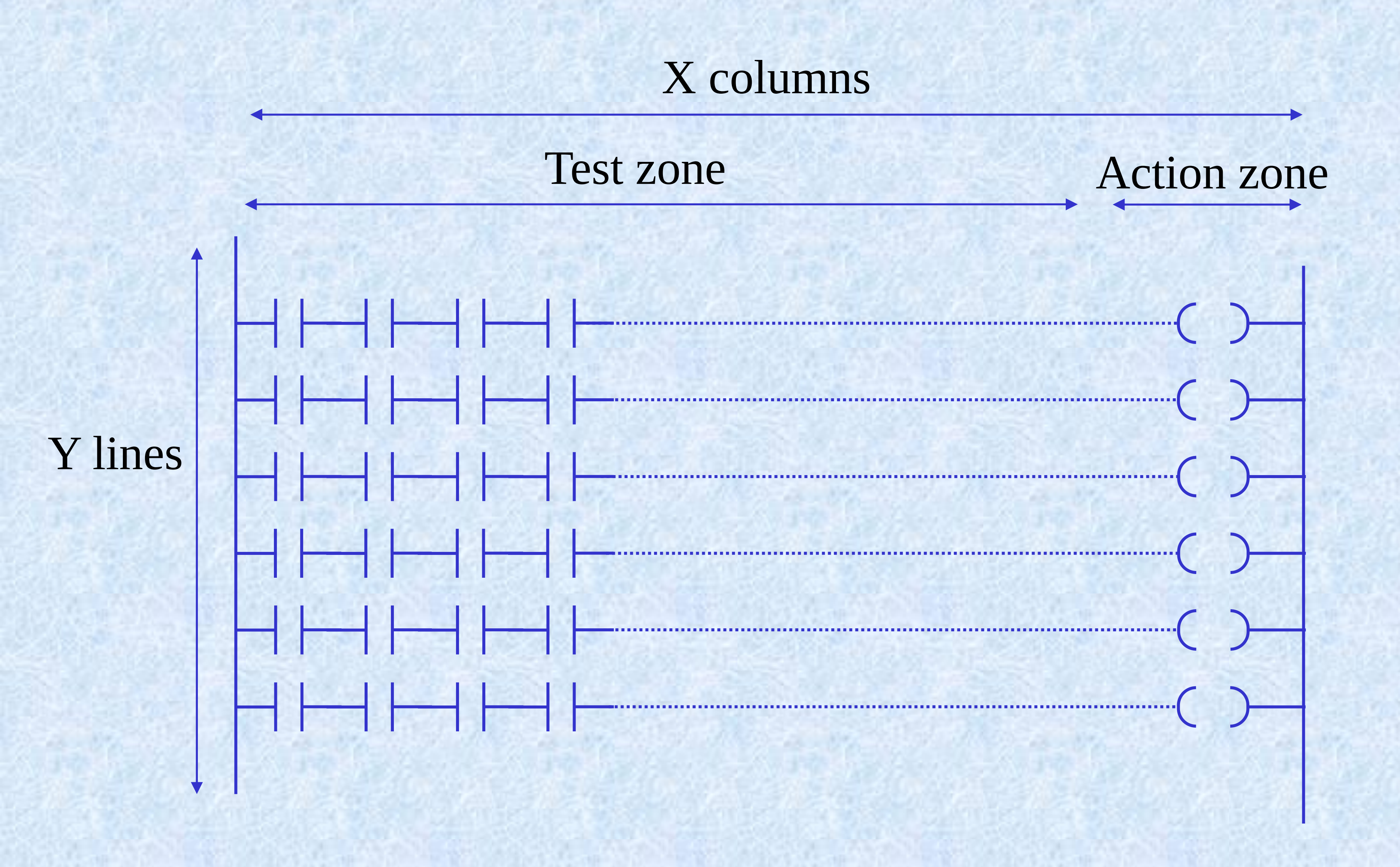
Sequential Function Chart (SFC)

- To describe sequential control function.
- steps & transitions represented graphically by a block or literally.
- Transition conditions in LD, FBD, IL or ST languages.
- Actions associated with the steps :Boolean variables or a section of the program written in one of the five languages.
- Association between action and steps in graphical or literal form.

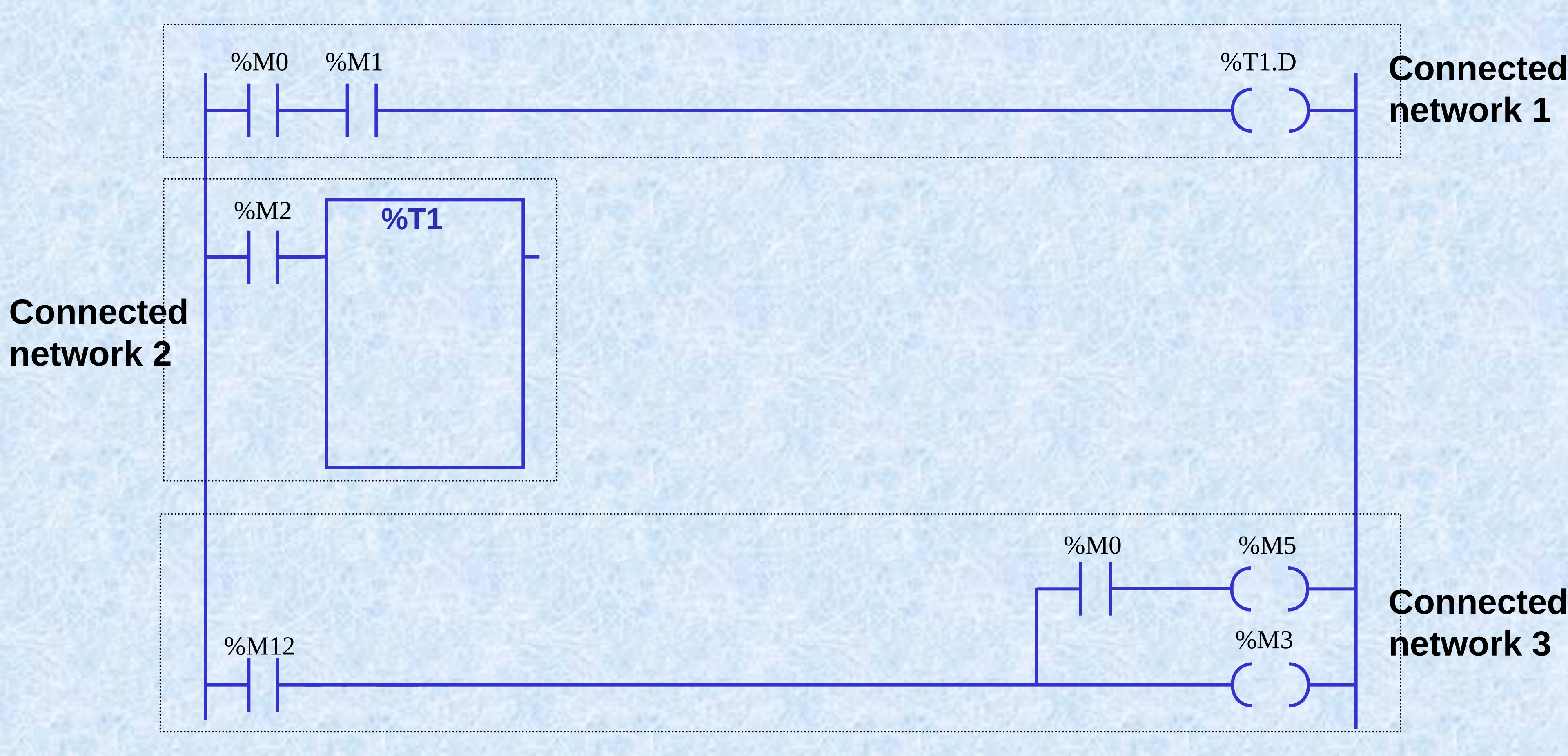
LD Language - Graphic Elements

N/O contact	—| |—	
N/C contact	—|/|—	
Rising edge detection		—|p|—
falling edge detection		—|N|—
Direct coil	—( )—	
Inverse coil	—(/)—	
Set coil		—(S)—
Reset coil		—(R)—

LD Language - Rung Structure

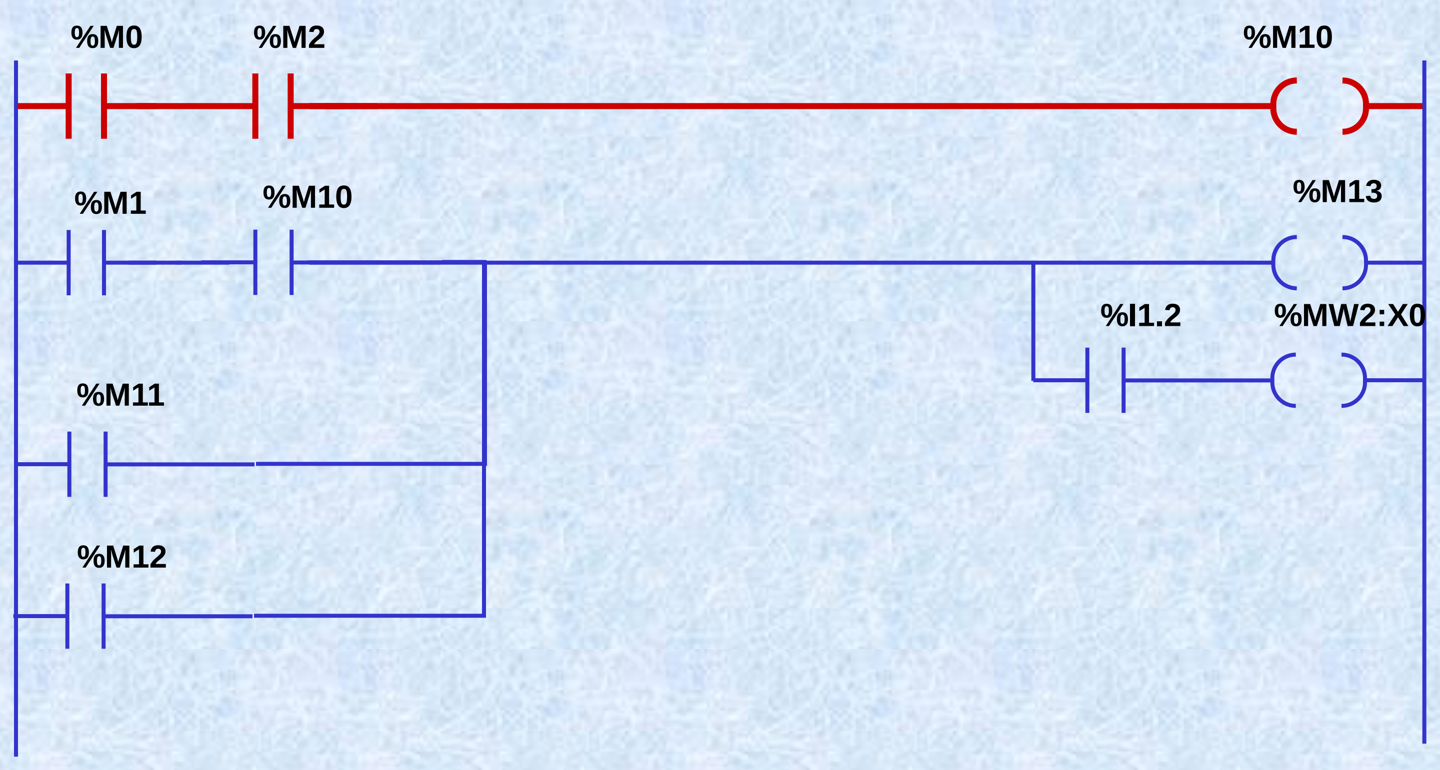


How a Ladder Rung is Executed



A network is executed from connected network, and within a connected network, in the direction of the equation: from top to bottom, line by line, and in each line from left to right

How a Ladder Rung is Executed Example



First coil evaluation (%M10)

Second coil Evaluation (%M13)

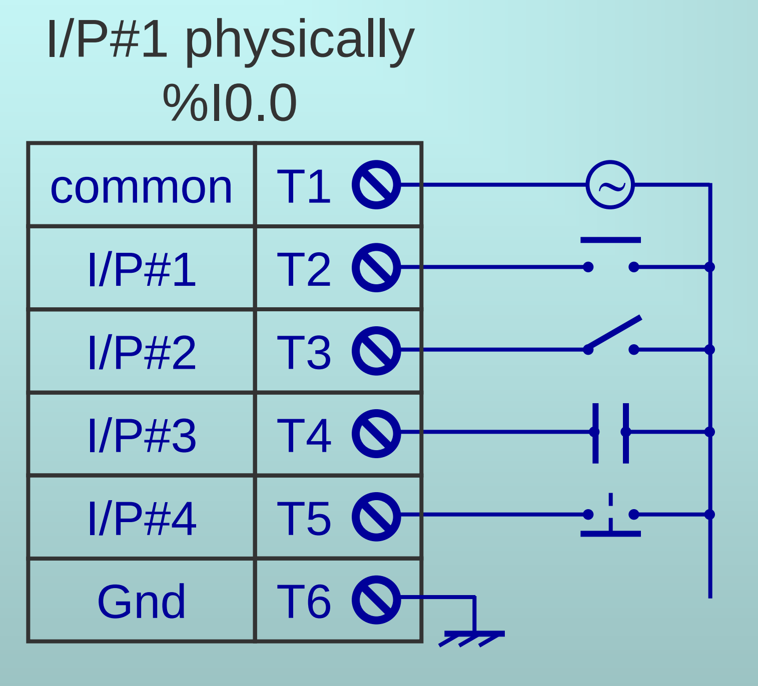
Third coil evaluation (%MW2:X0)

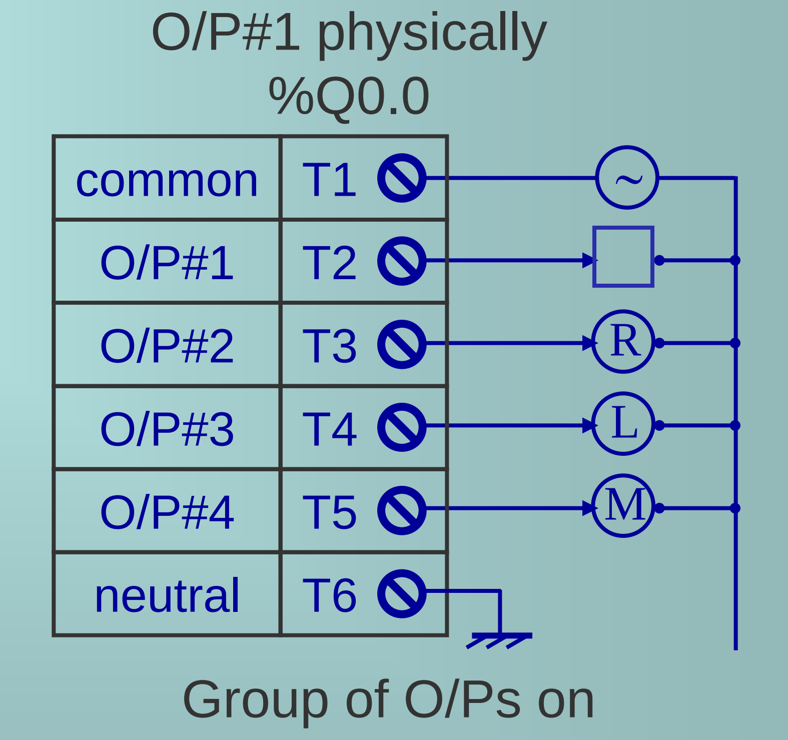
BASIC Programming



I/P Addressing

Each input or output is assigned a number on its module, which is referenced to within the program which is refereed to as “address”.





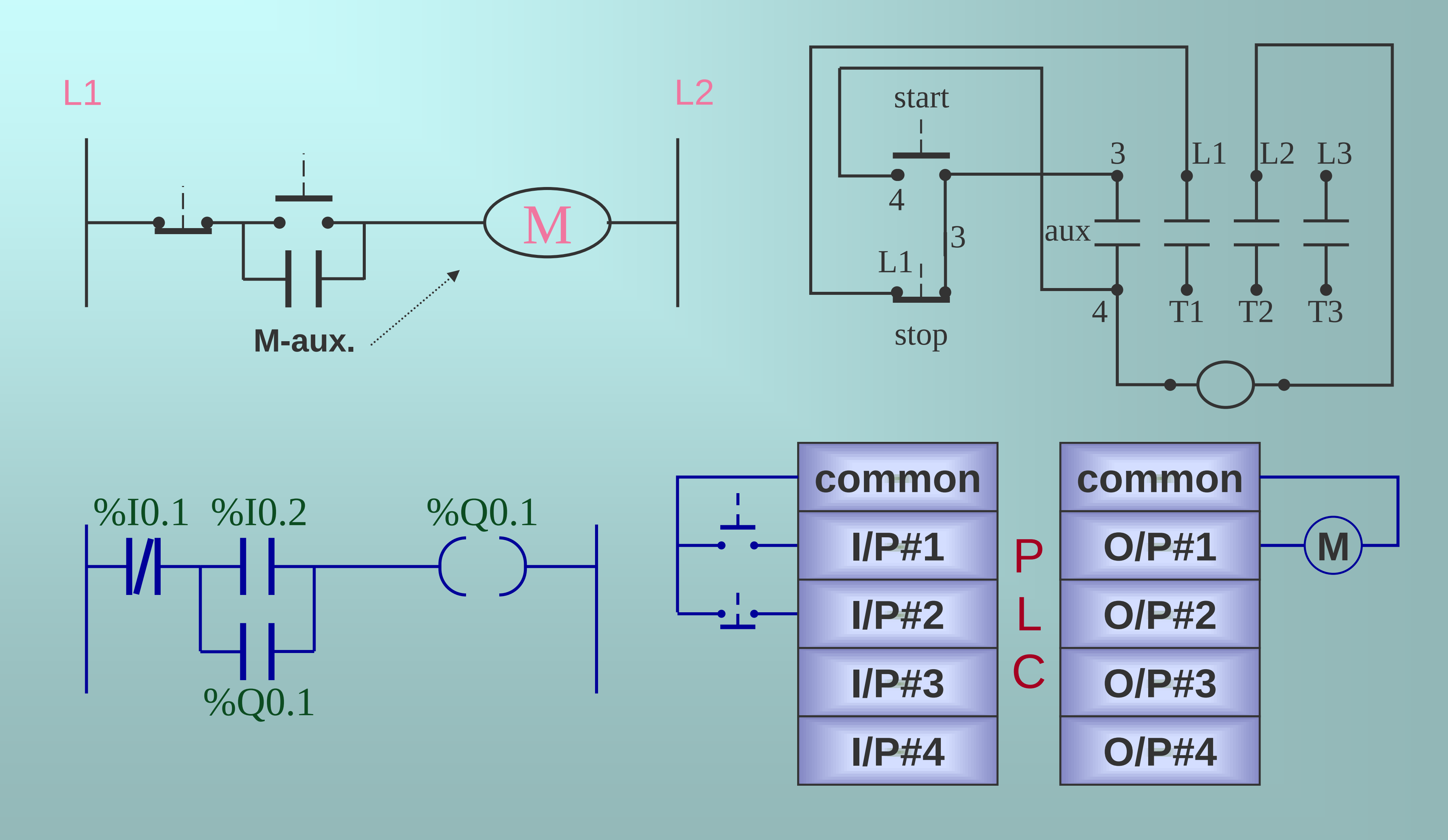
Group of I/Ps on

an AC I/P module

Group of O/Ps on

an AC I/P module

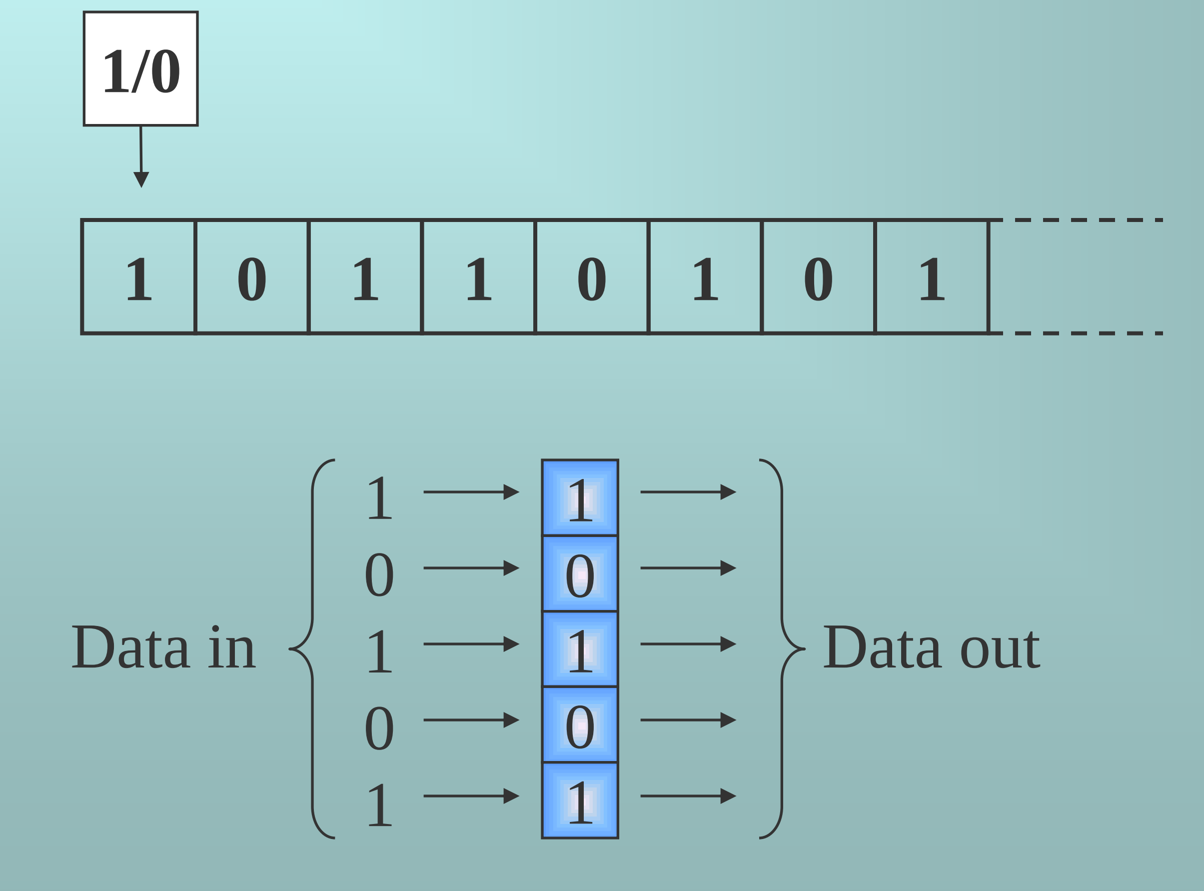
Ladder Logic Vs Conventional Control



Registers

Register is a storage of individual bits.

Data other than simple two state binary can be handled in and out by registers.

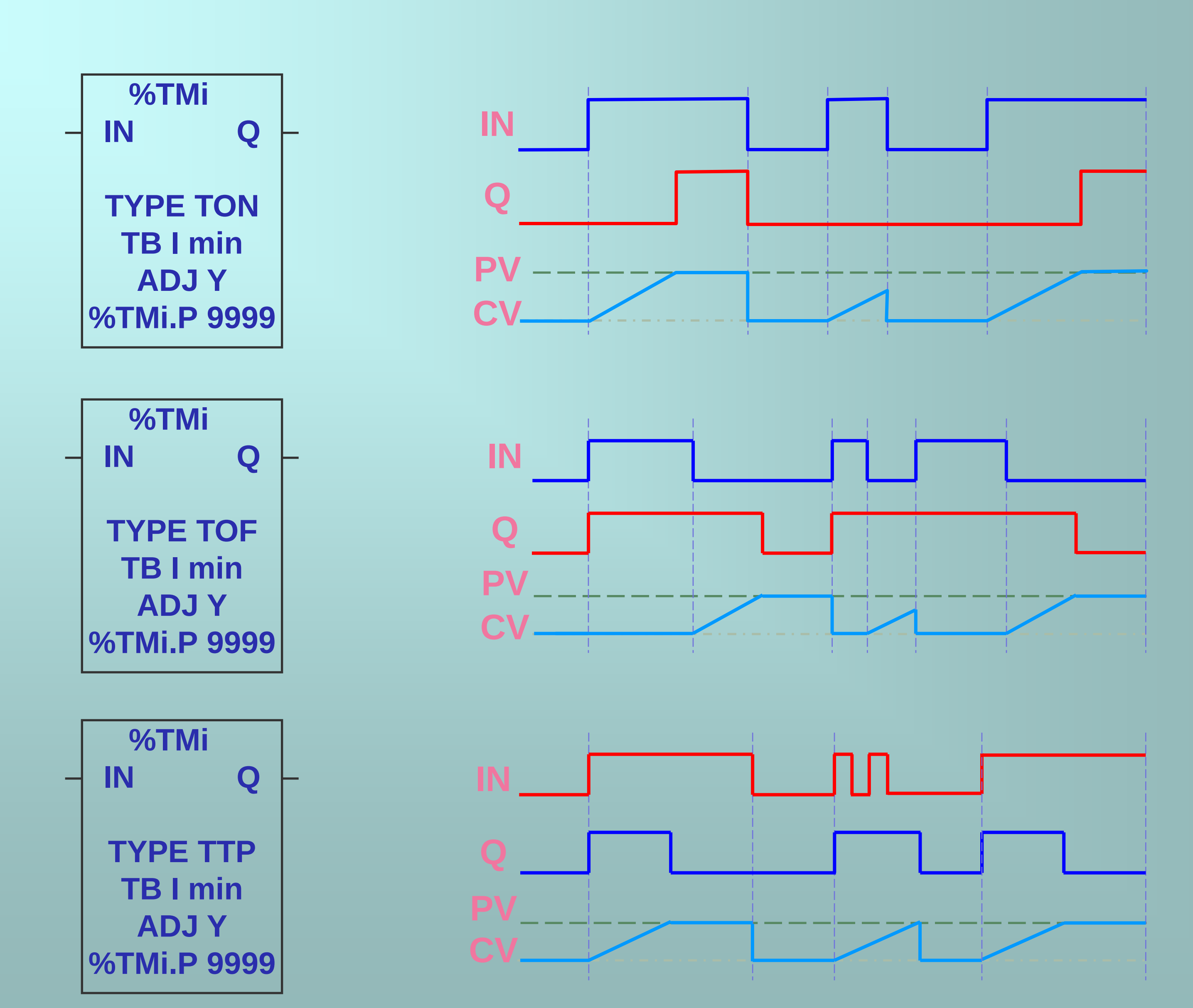


Timers

- PLC TIMER
- programmable variable time as well as fixed time with large time span

On DELAY.
OFF DELAY.
limited ON TIME.
“one shot” operation.
Multiple on delay.
Industrial timers.
Digital,Solid state.
Electronic timers.
etc………

Time Charts



%TMi
IN
Q
TYPE TON
TB I min
ADJ Y
%TMi.P 9999
IN
Q
PV
CV
%TMi
IN
Q
TYPE TOF
TB I min
ADJ Y
%TMi.P 9999
IN
Q
PV
CV
%TMi
IN
Q
TYPE TTP
TB I min
ADJ Y
%TMi.P 9999
IN
Q
PV
CV

Counters

%C8

Contact	Input	Output
%I0.1	R	E
	S	D
%I0.2, %M0	CU	F
	CD	

ADJ Y
%C8.P 9999

%C8.D —| |— ( ) %Q0.2

Count x

Reset

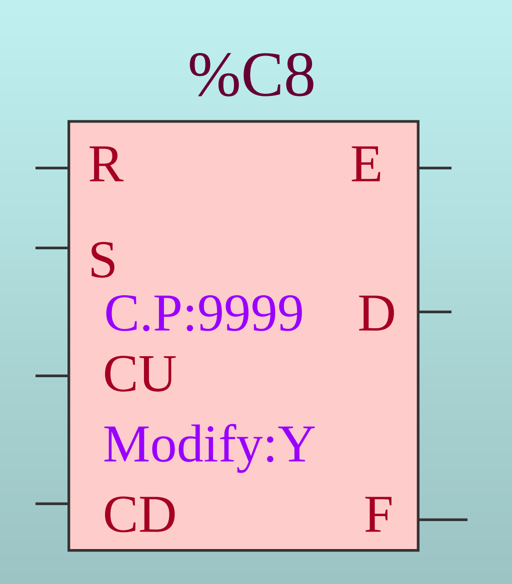
Pv

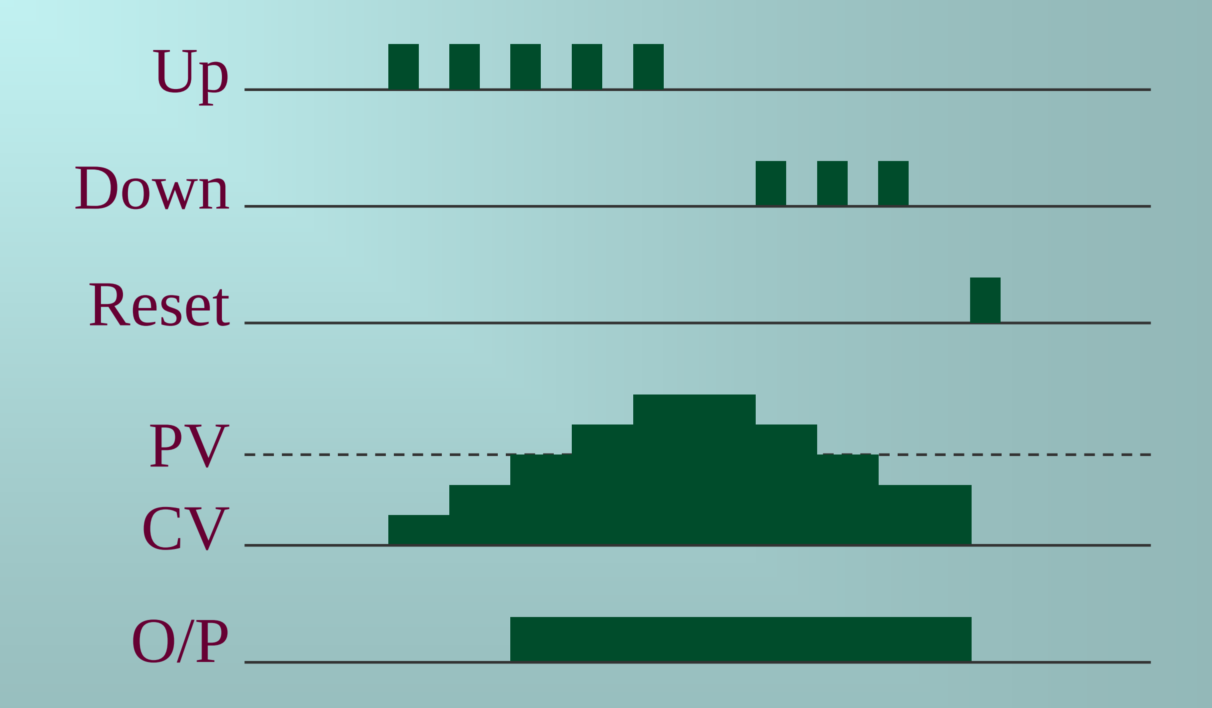
Cv

O/P

Up Counter

Up/Down Counters

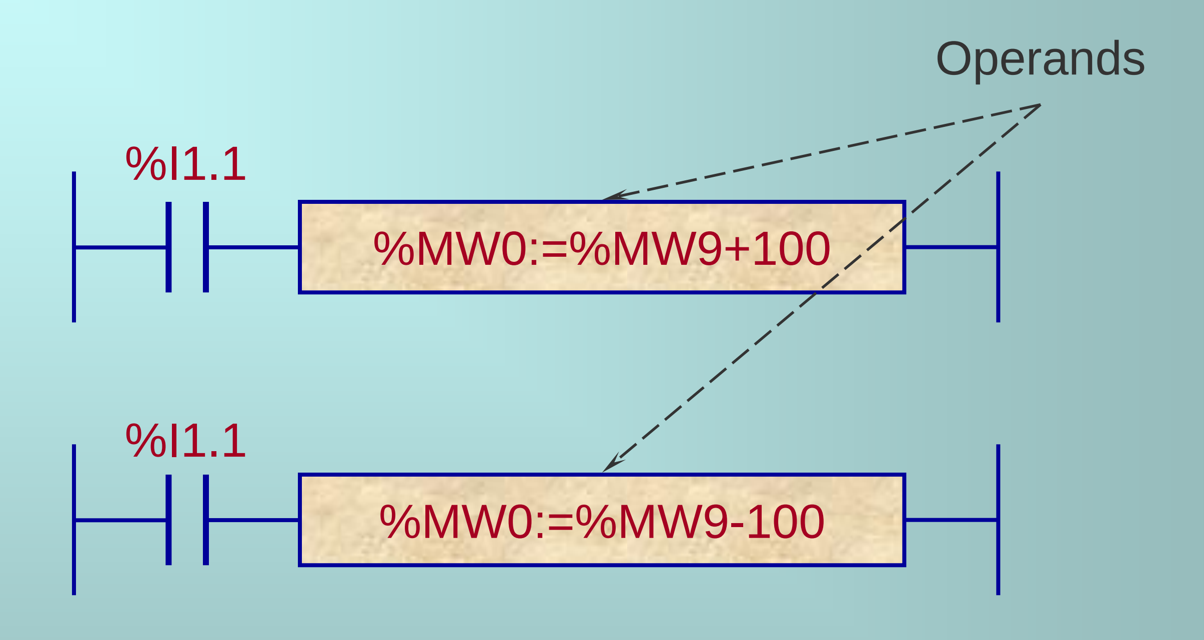




Arithmetic Functions

Addition
Subtraction
Multiplication
Division
Square Root
etc.

Add & Subtract



OPERAND: a register containing a numerical value used in an arithmetic operation as an input

Multiply & Divide



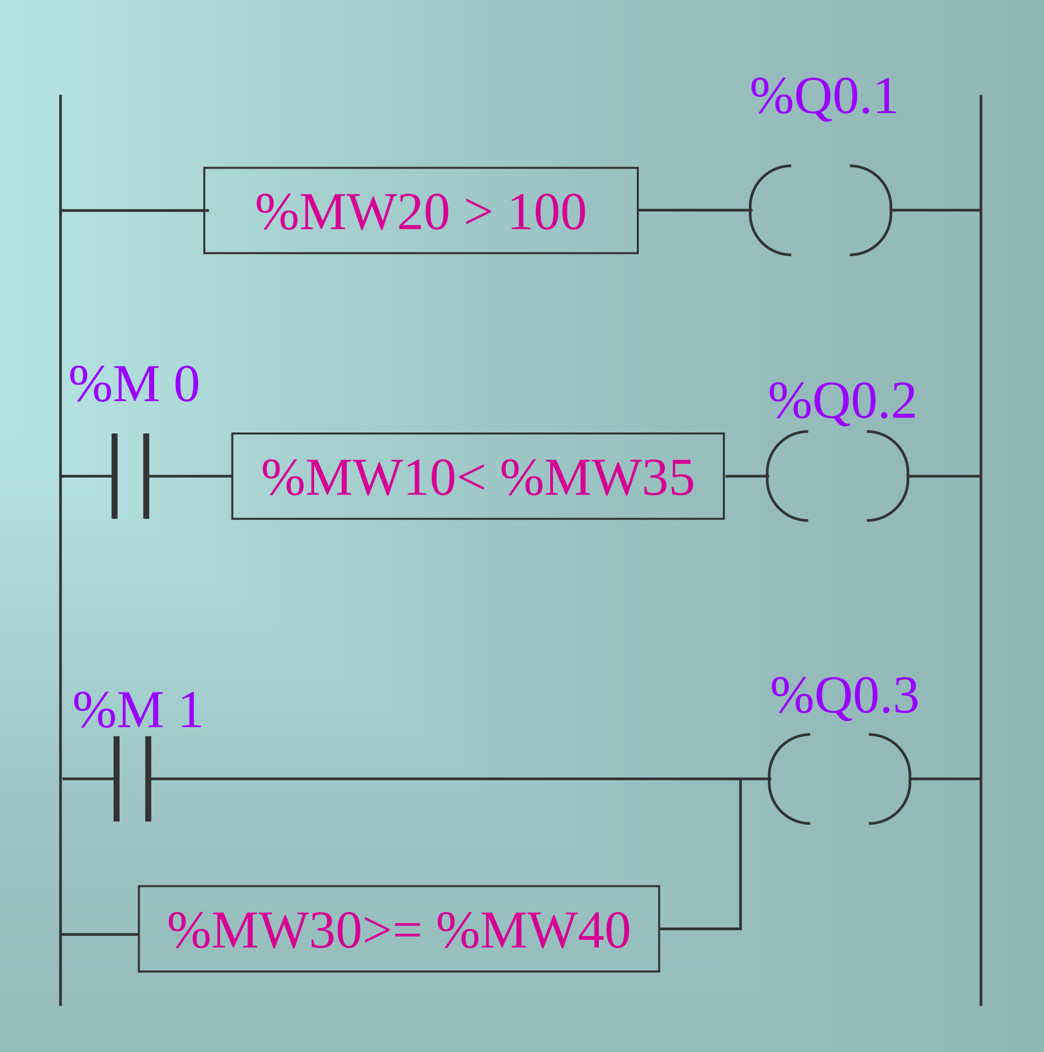
Square Root

%I1.1

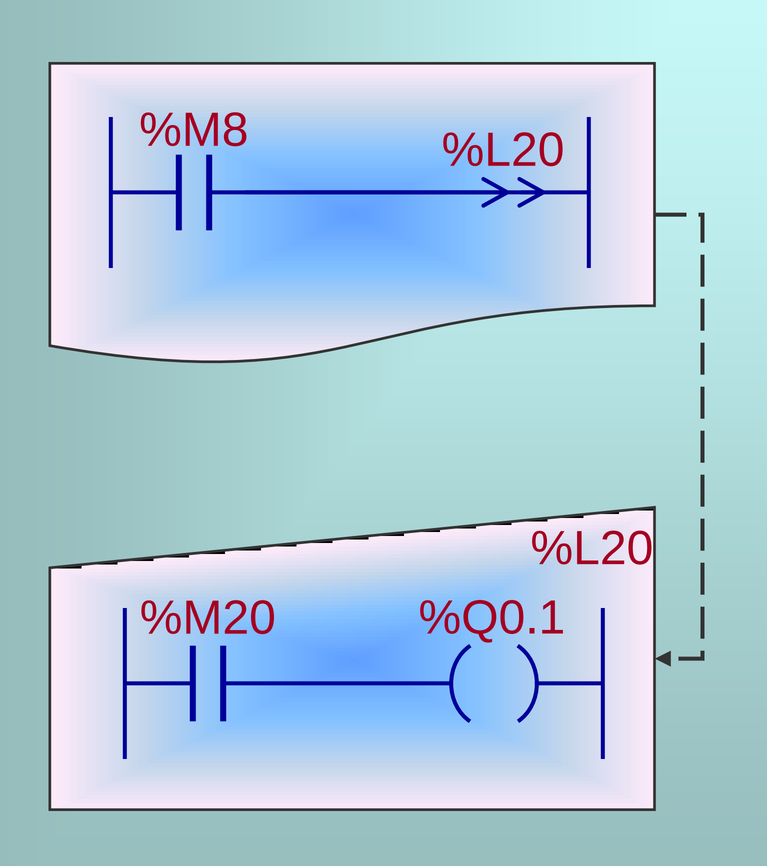
%MW0:=SQRT(%MW9)

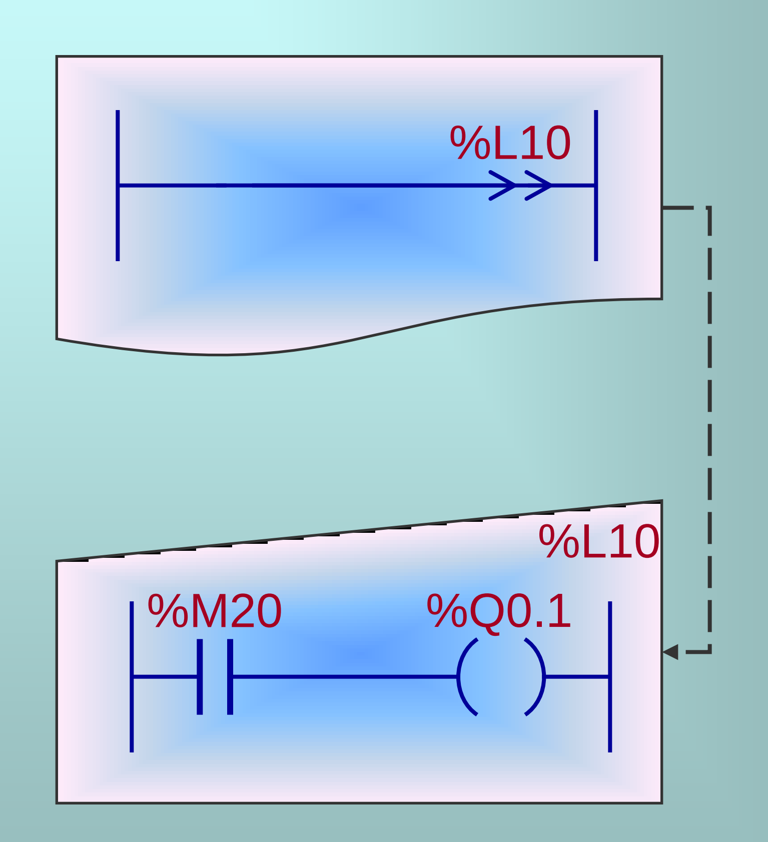
Comparison Instructions

- > Greater Than
- >= Greater Than or Equal
- < Less Than
- <= Less Than or Equal
- = Equal
- <> Different From

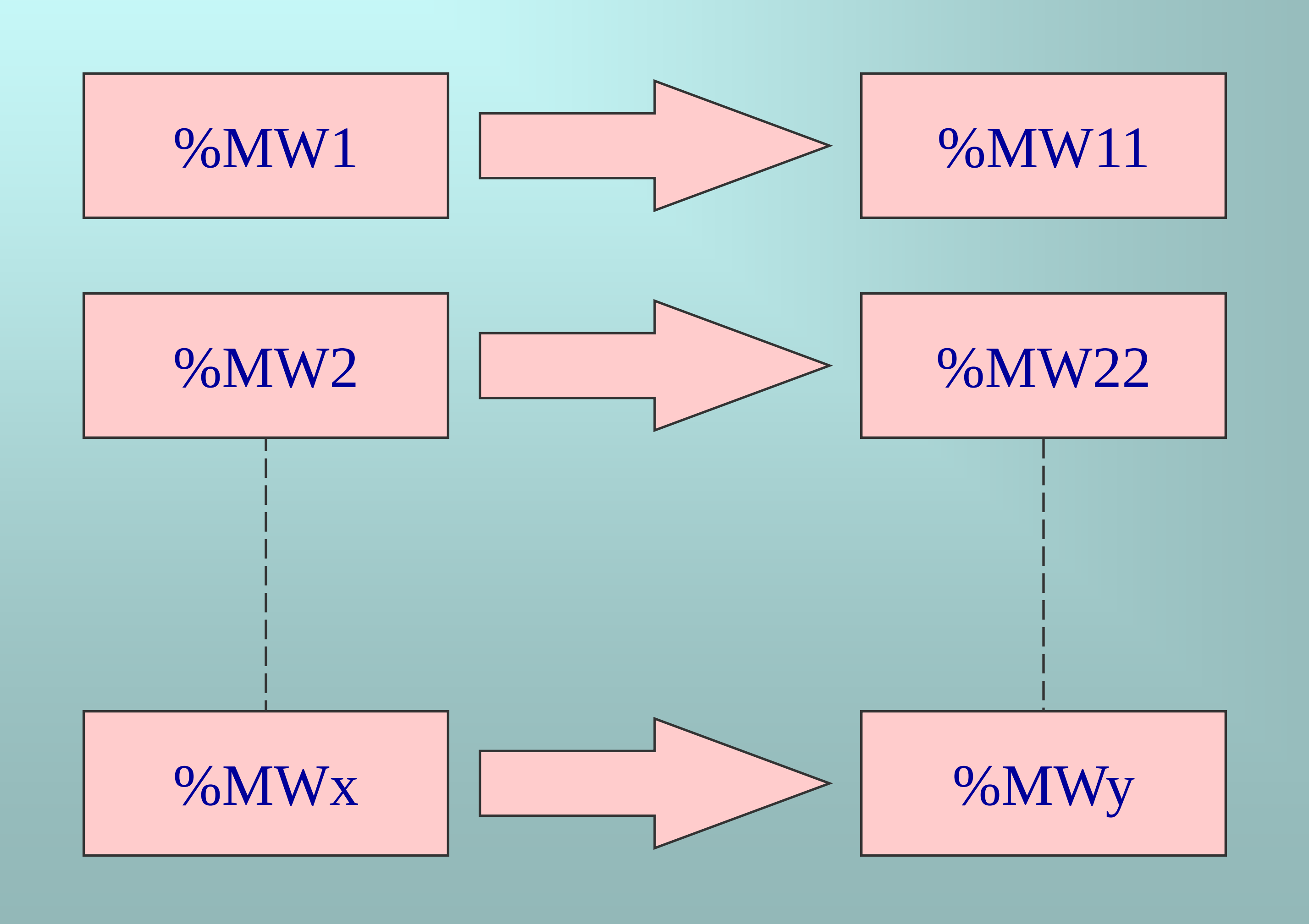


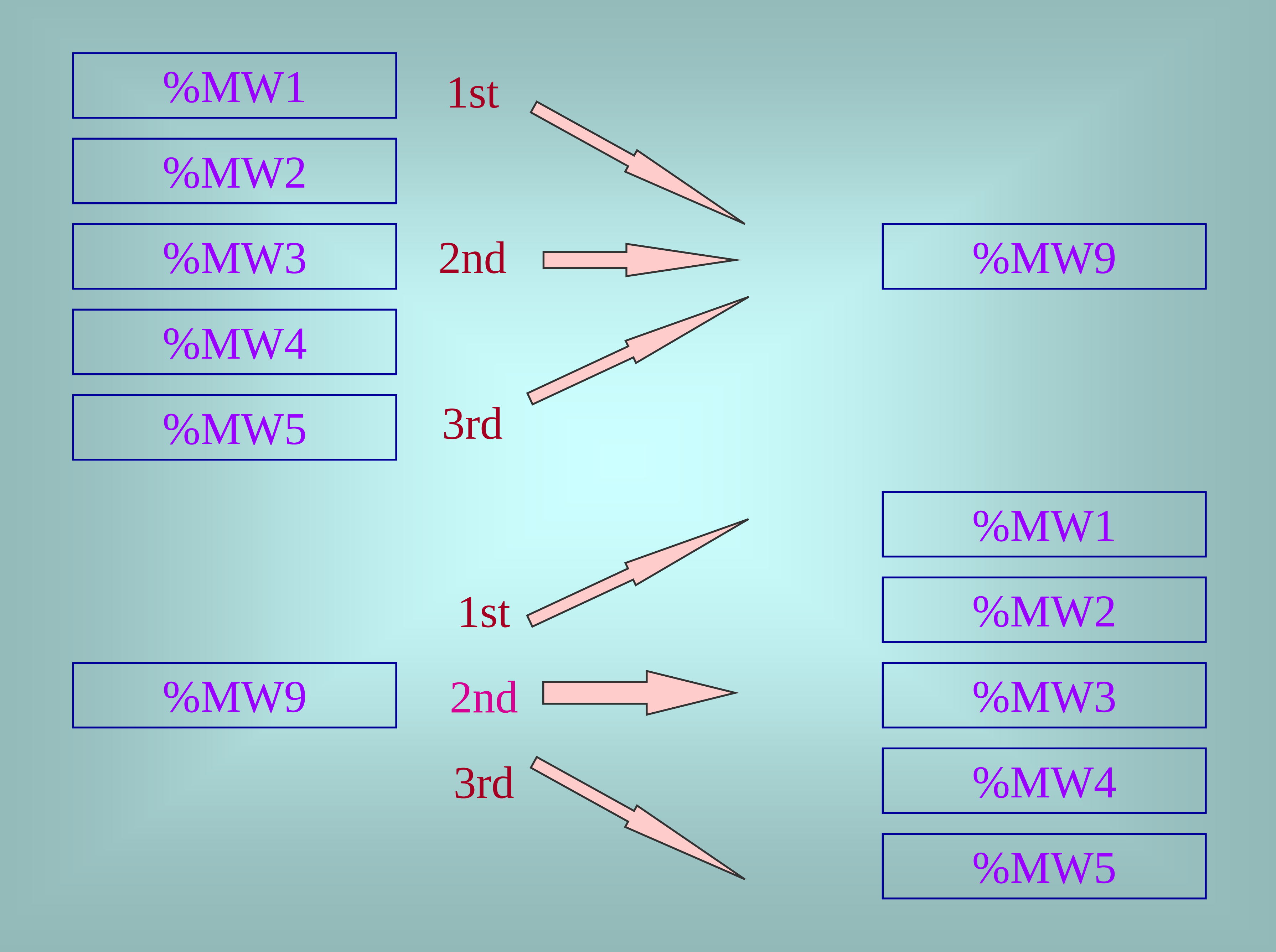
Jump Instructions





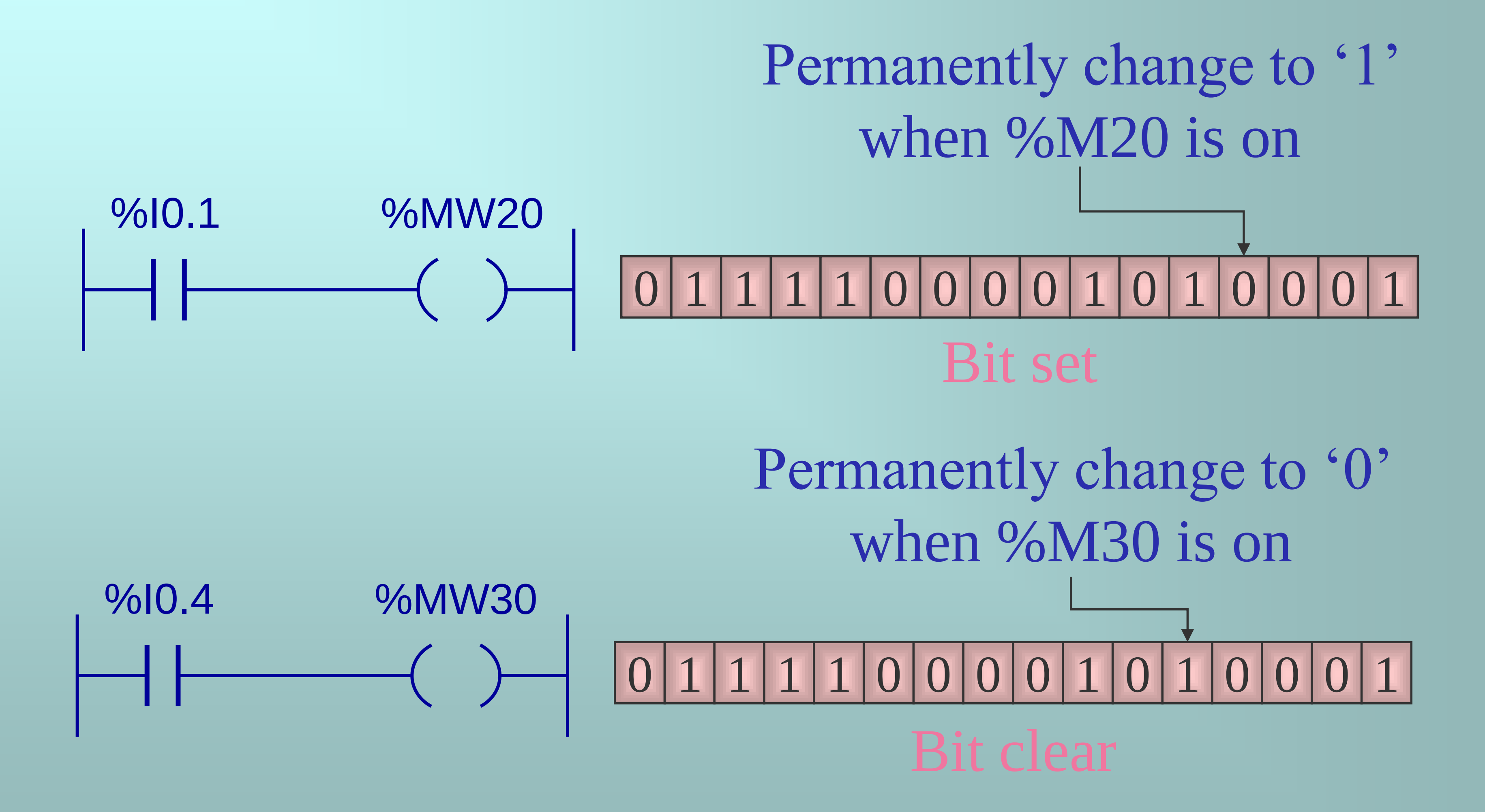
Data Move



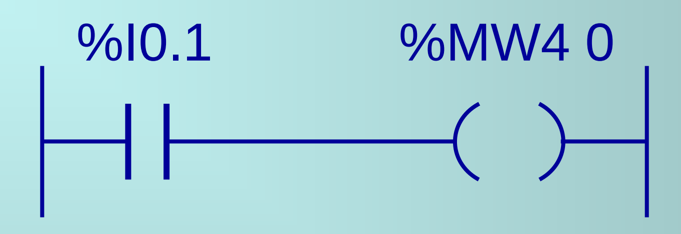


%MW1
1st
%MW2
%MW3
2nd
%MW9
%MW4
%MW5
3rd
%MW1
1st
%MW2
%MW9
2nd
%MW3
3rd
%MW4
%MW5

Bit Operations

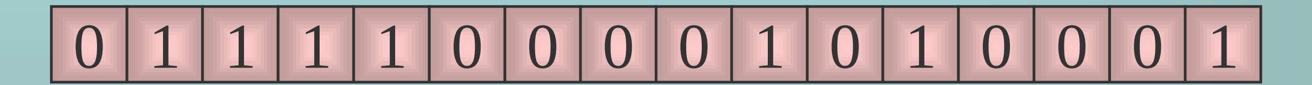


Bit Operations - Bit Follow

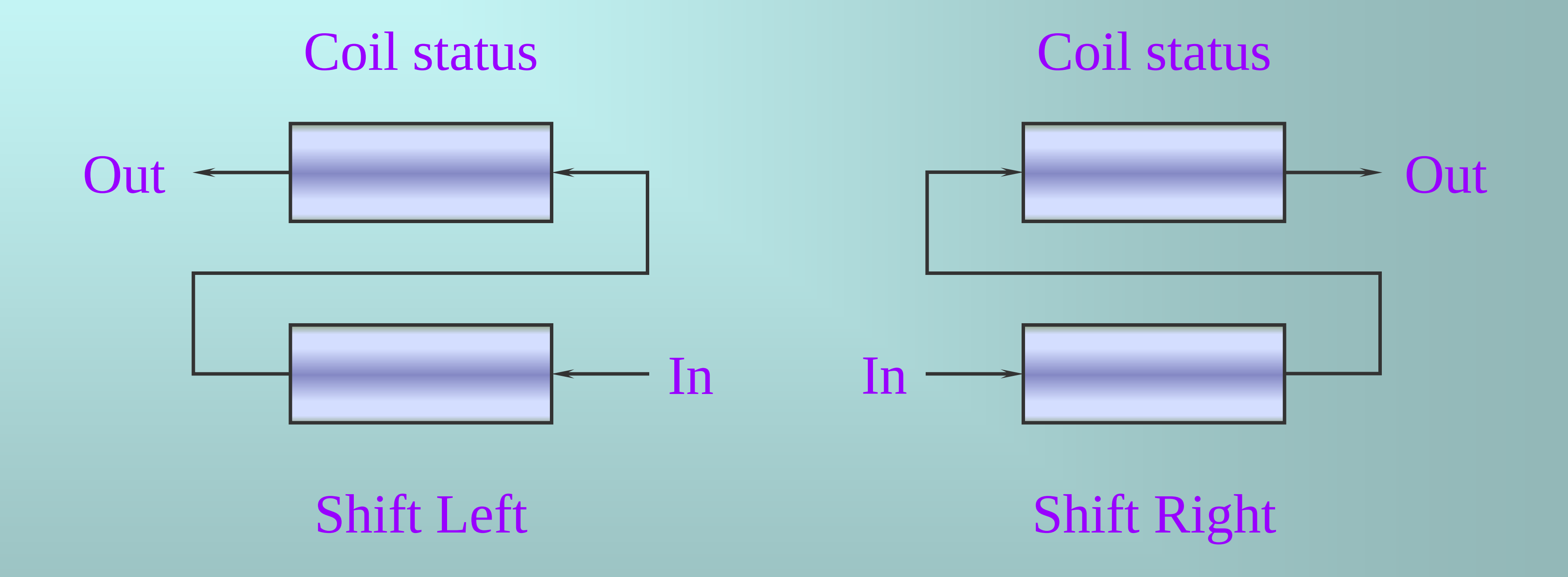


" 0 " when %MW40 is on

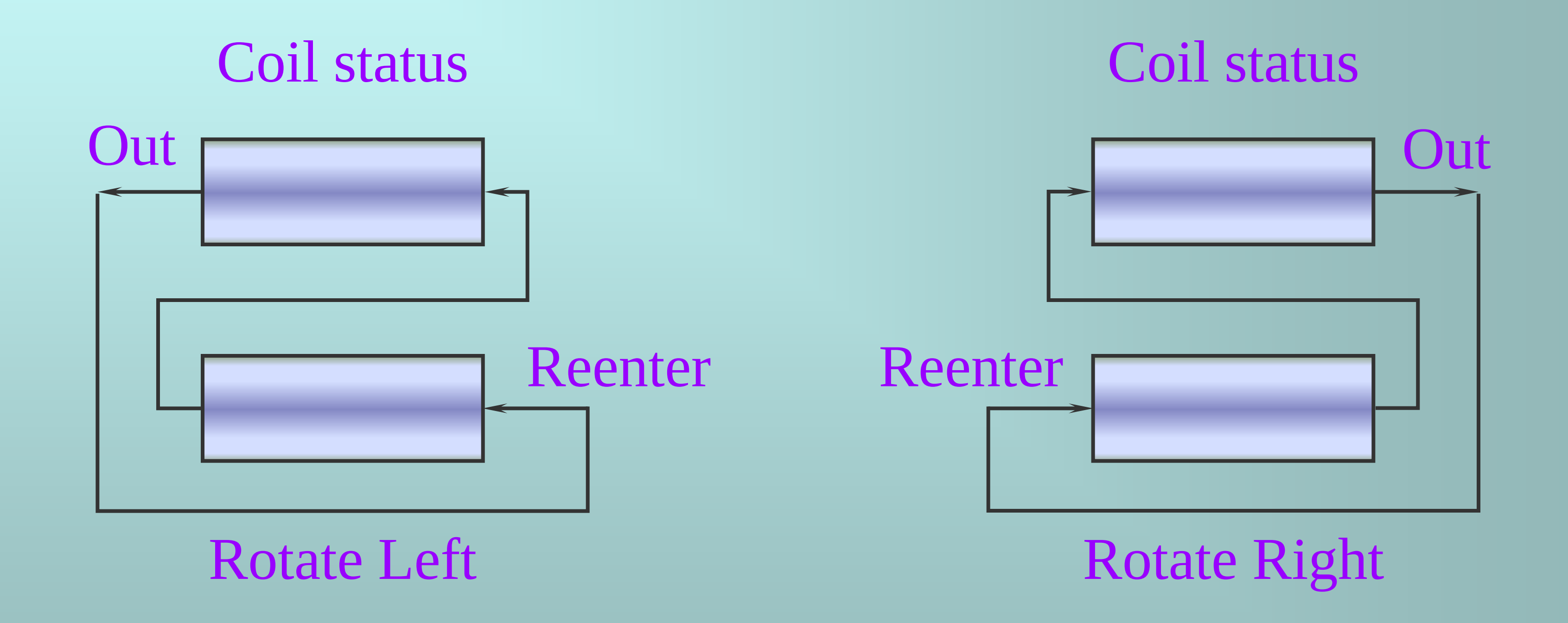
" 1 " when %MW40 is off



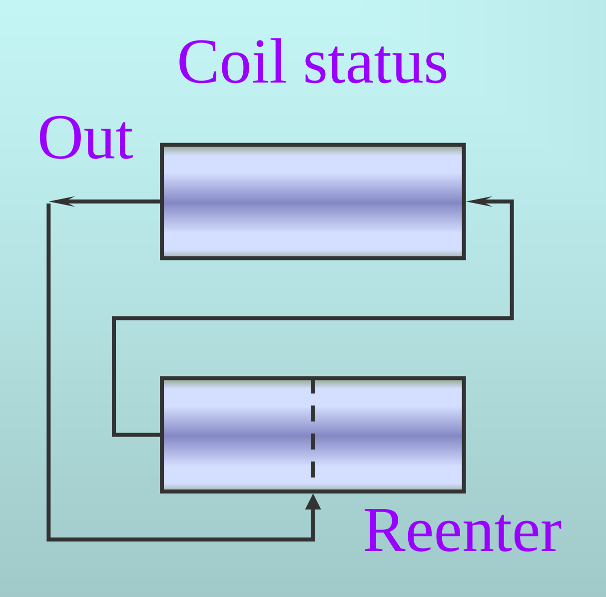
Shift Register



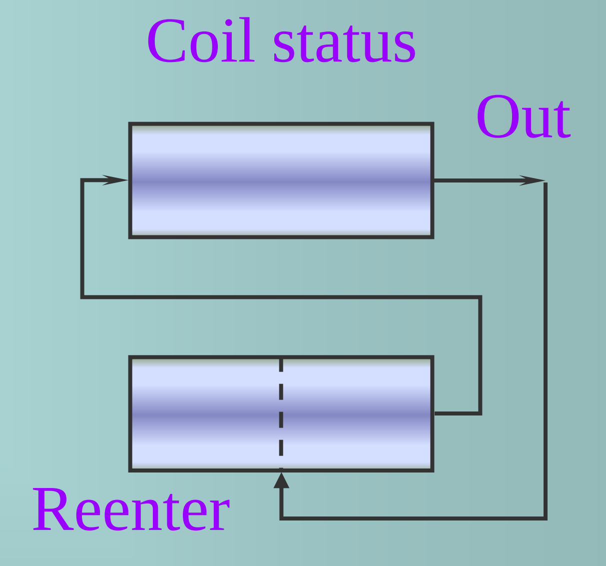
Shift Register - Rotate Full



Shift Register-Rotate Partial

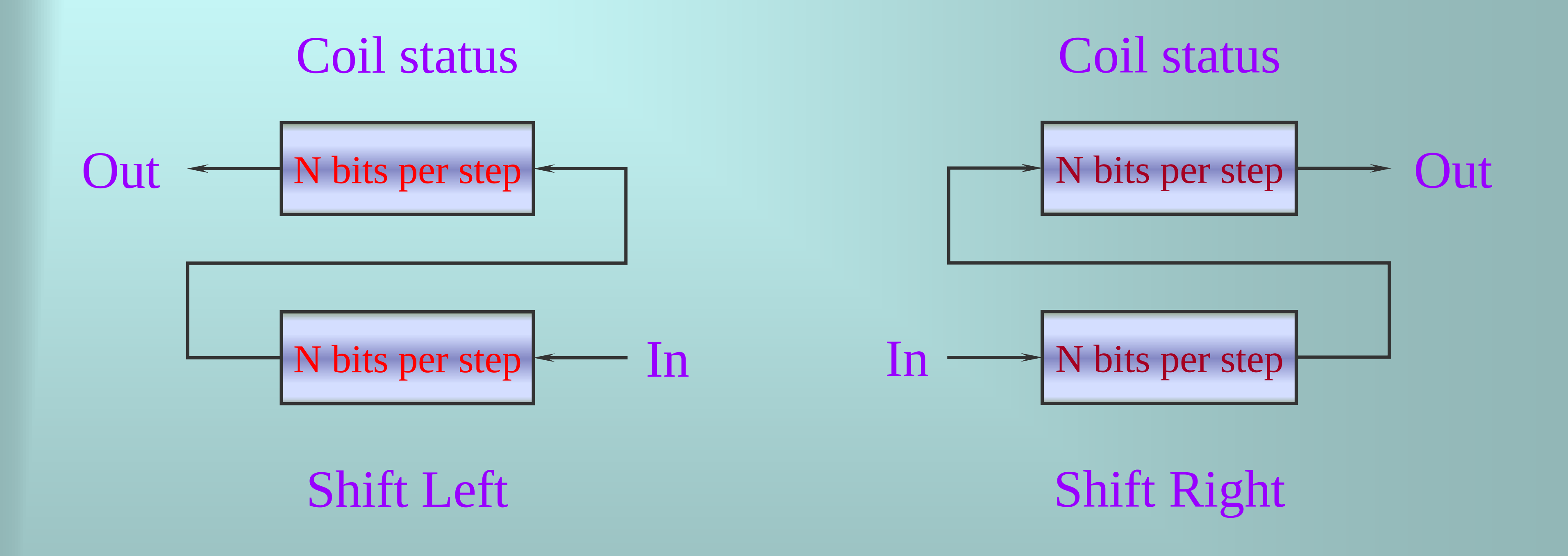


Rotate Left



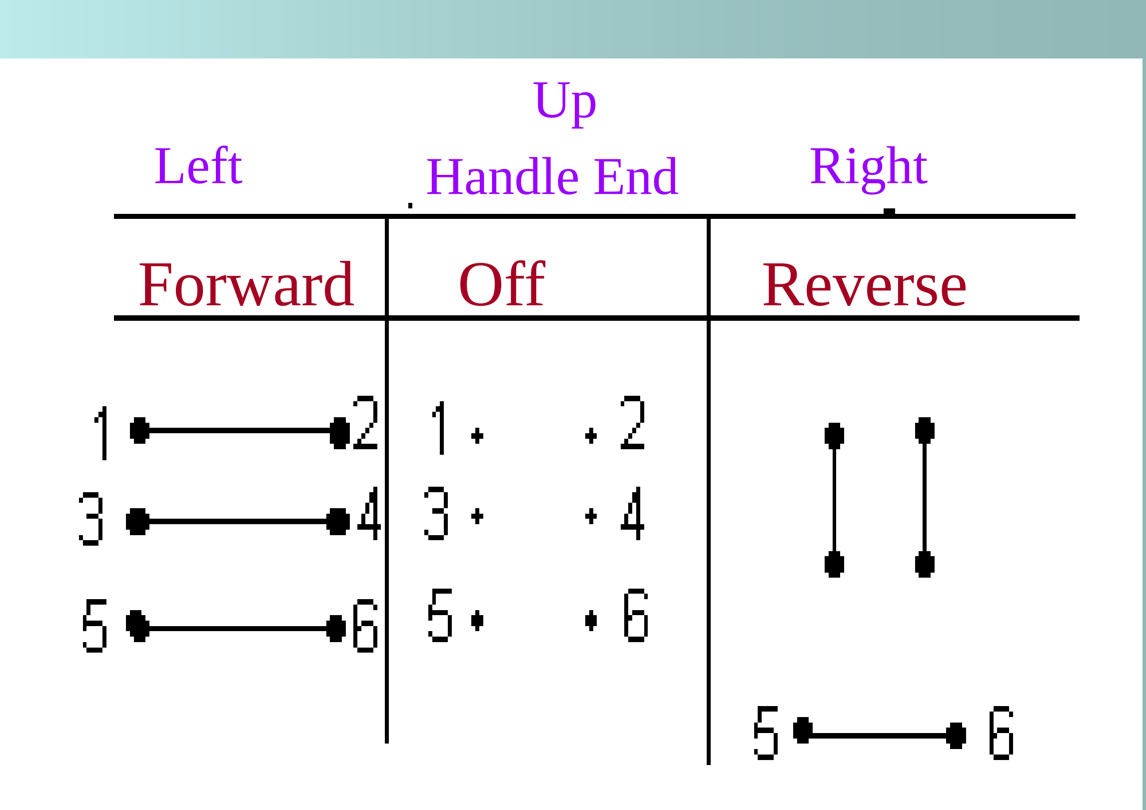
Rotate Right

Shift Register - Multi - bit

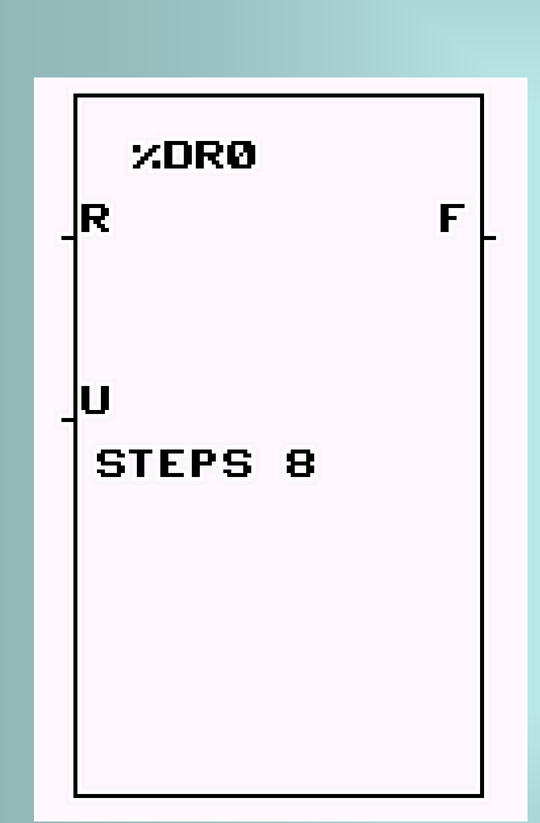


E/M Drum Sequencer

Electromechanical drum controller is a 3 position / 6 terminal device it is an economical control device for handling applications with a fixed sequence and a limited number of required contacts

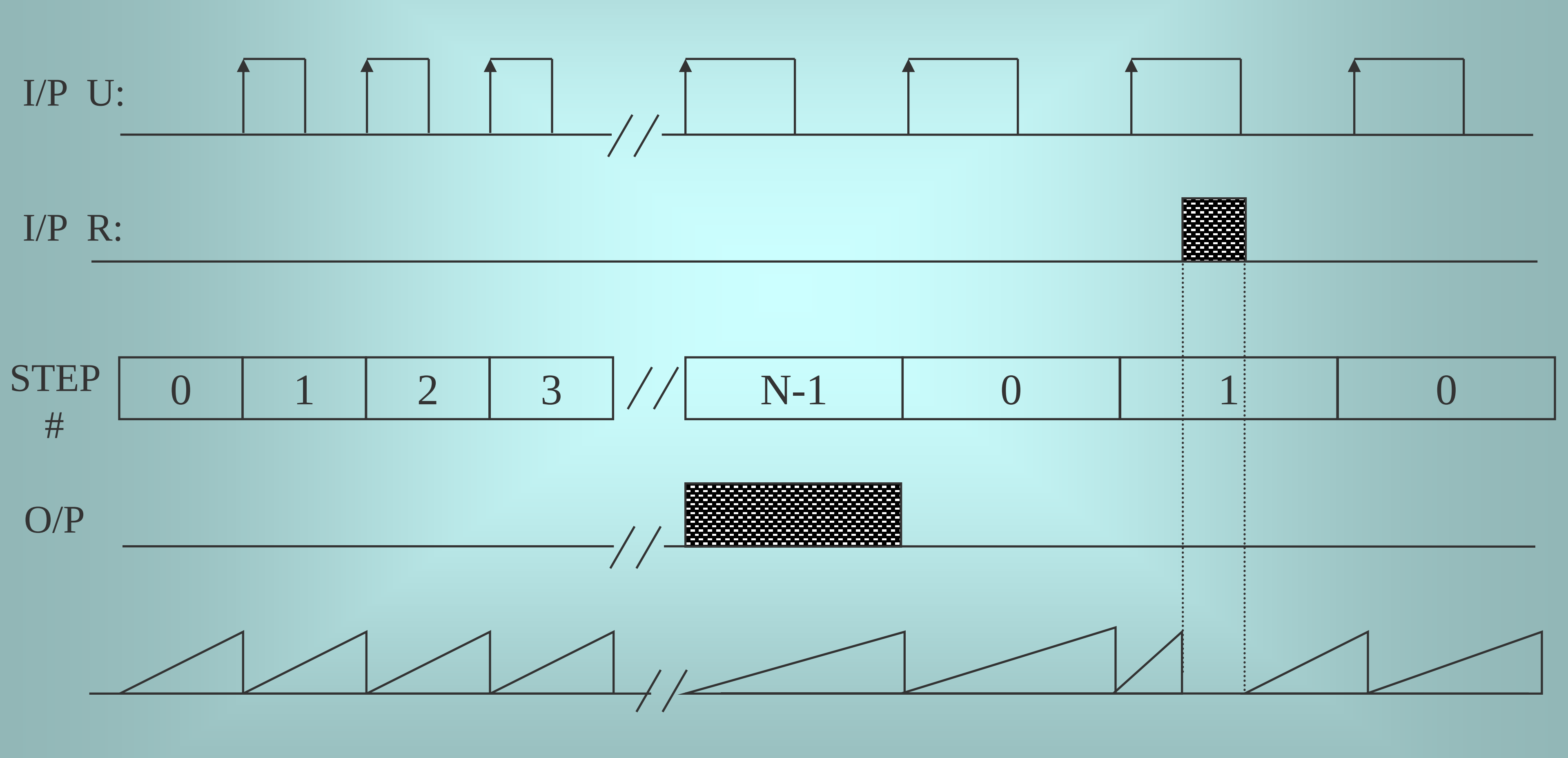


PLC Sequencer

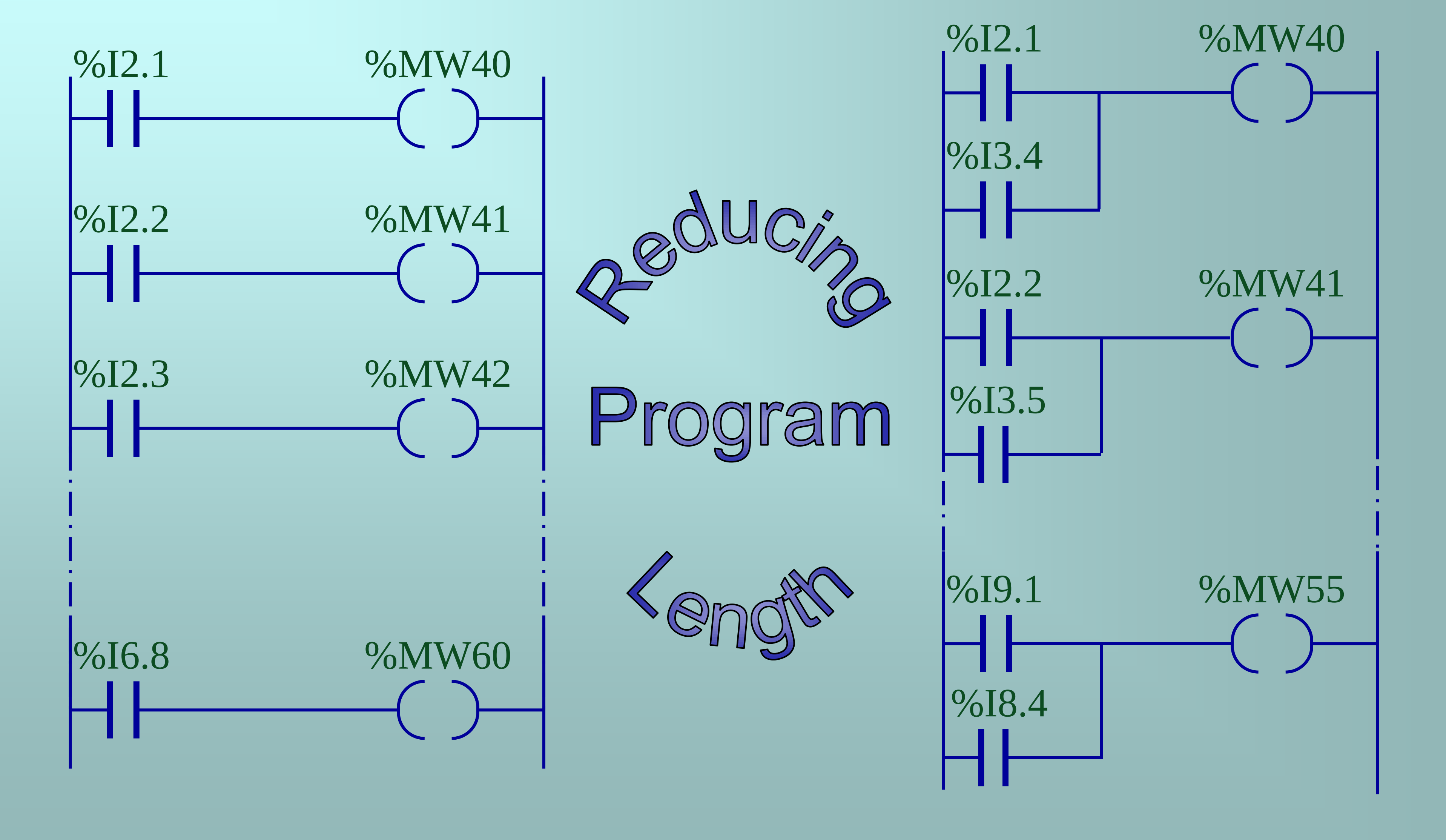


PLC sequencer operates on a similar a principle to an electromechanical drum controller, which changes step according to external events. On each step, the high point of a cam gives a command which is executed by the control system. In the case of a drum controller (PLC sequencer), these high points are symbolized by state 1 for each step and are assigned to output bits or internal bits, known as control bits.

Operating Diagram

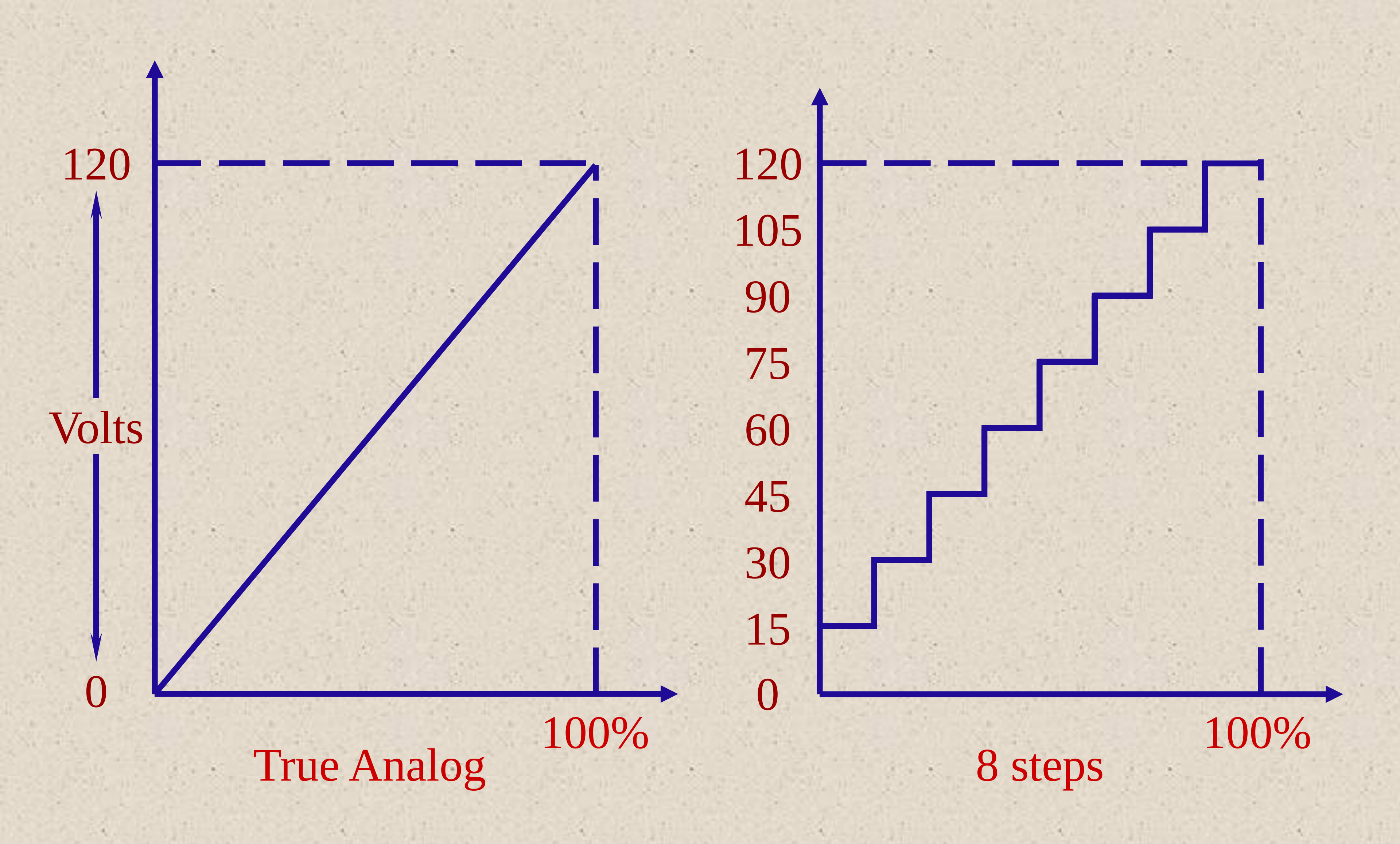


Matrix Function

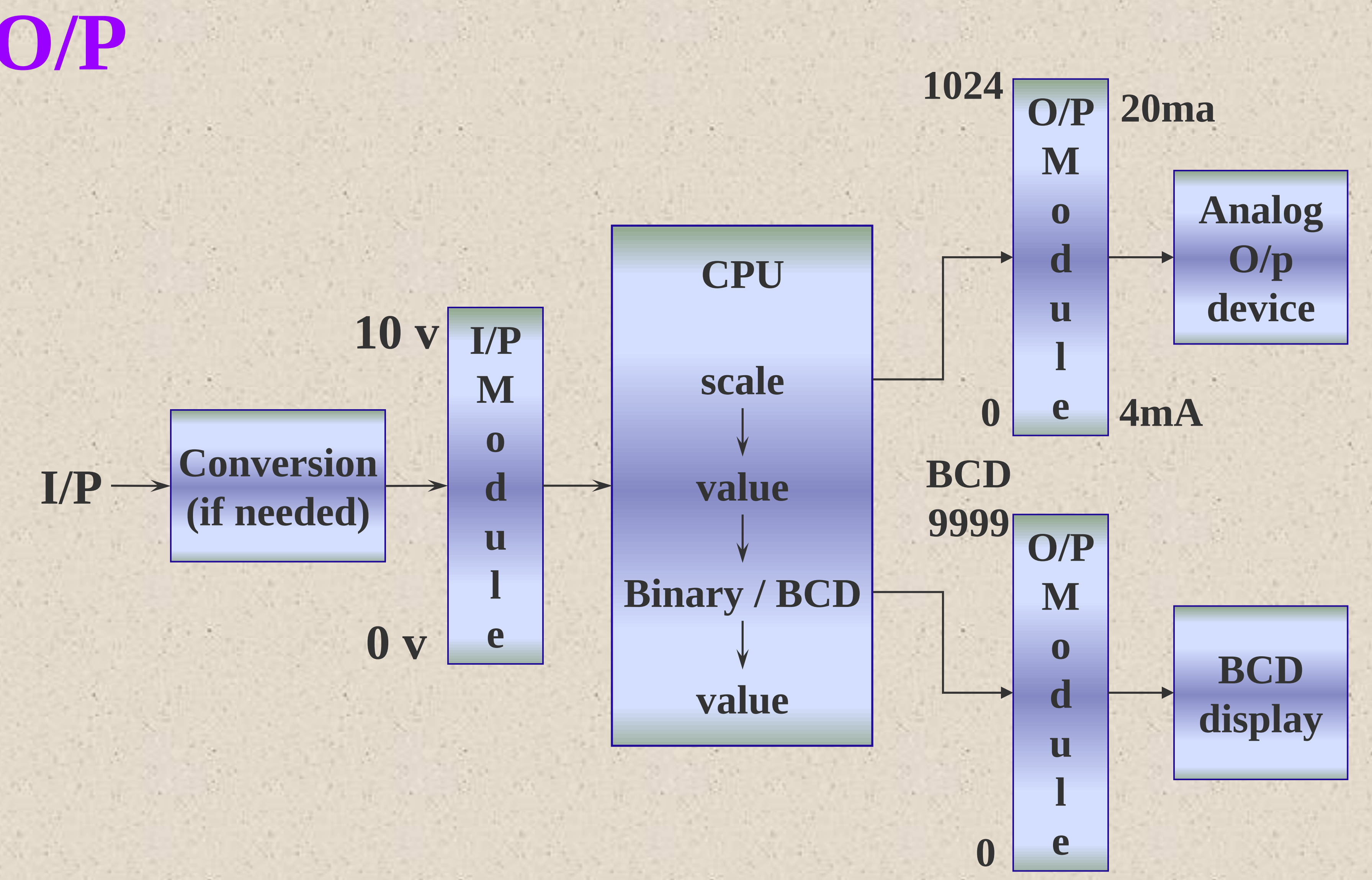


Advanced Programming

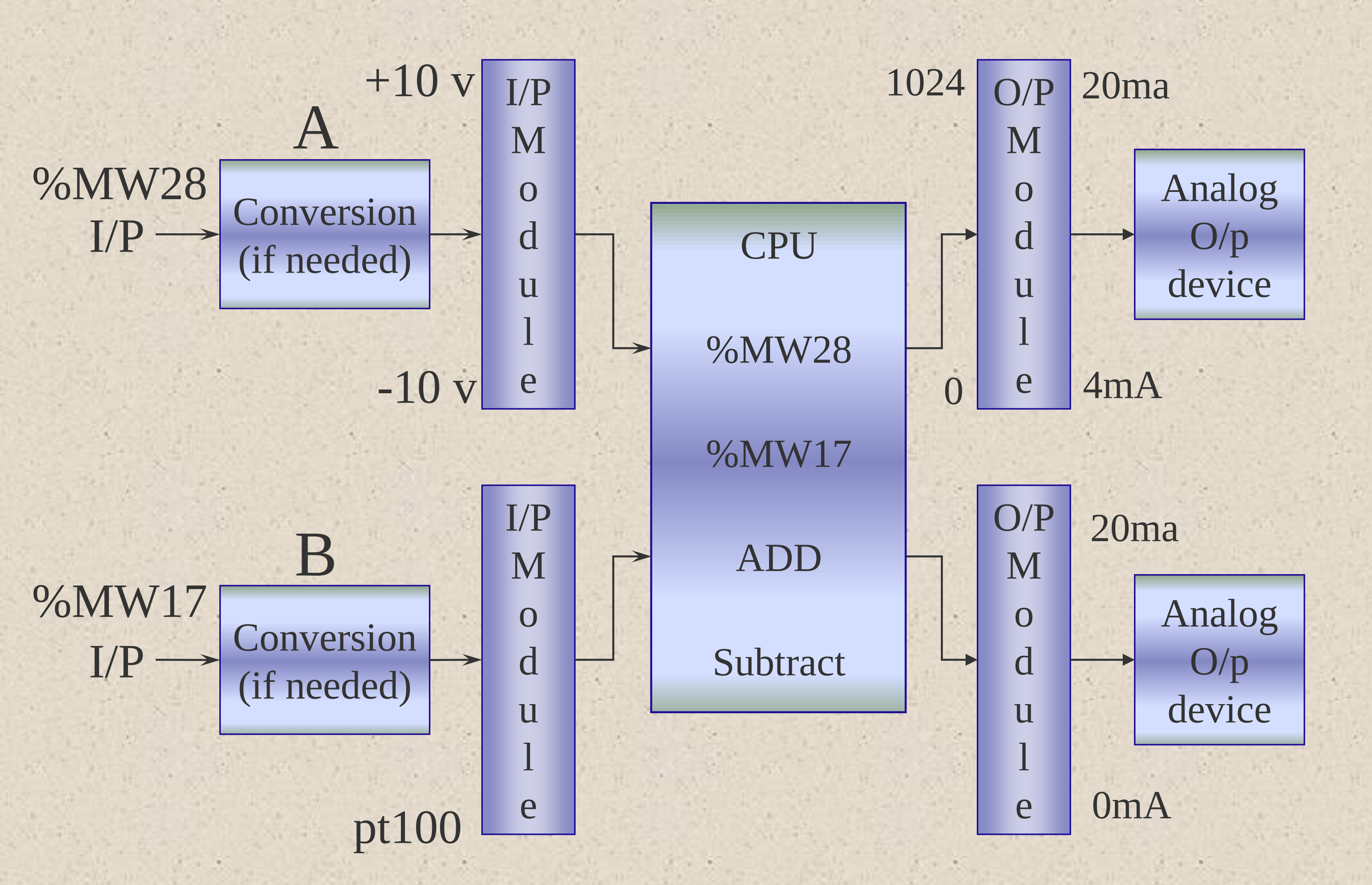
Analog Operation



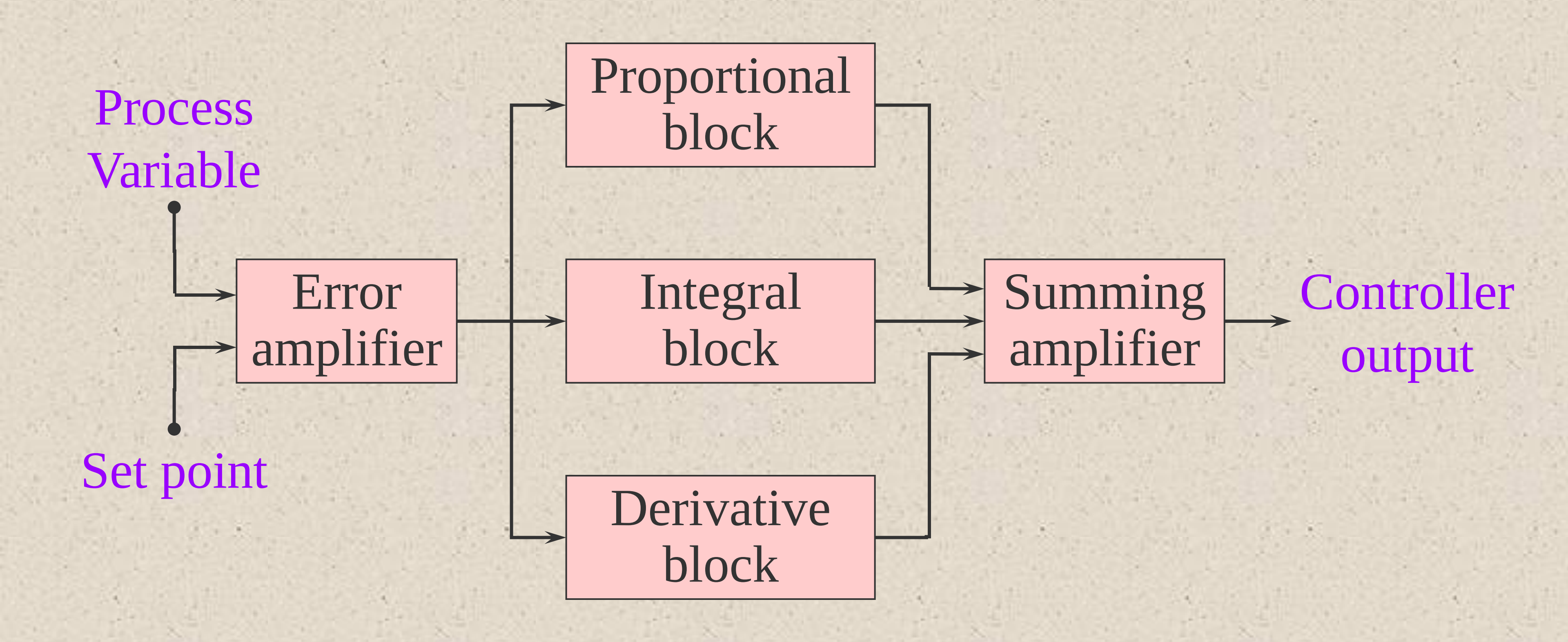
Examples:- Analog I/P / Analog or BCD O/P



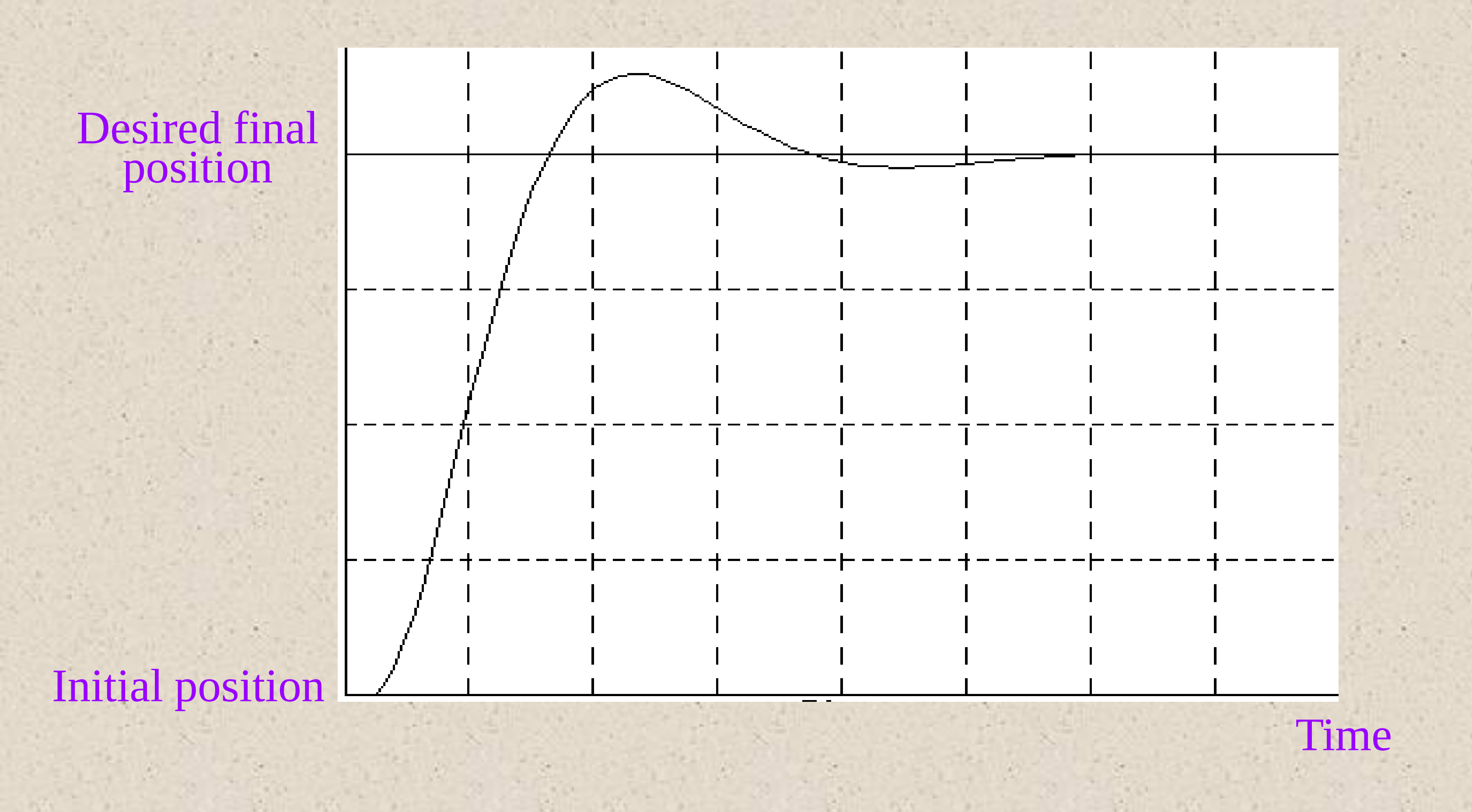
Examples:- 2 Analog In /2 Analog Out



PID Principles



Ideal PID Control Curve



Typical Process Control Curves

Position (degree)
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8
Elapsed time in seconds

Position (degree)
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8
Elapsed time in seconds

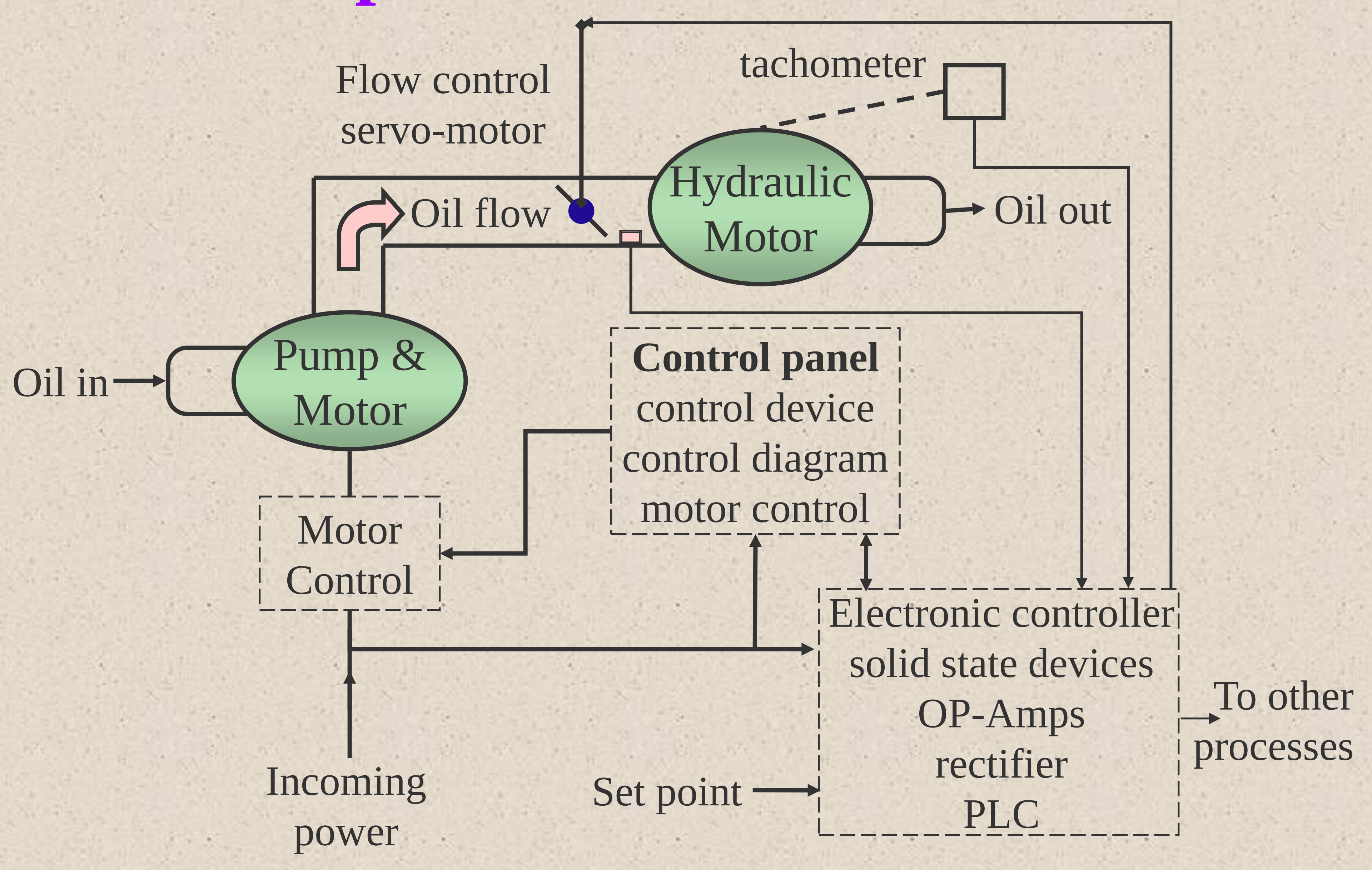
Desired final position
Initial position
Time

Desired final position
Initial position
Time

Desired final position
Initial position
Time

Desired final position
Initial position
Time

PID Example



Flow control
servo-motor
tachometer
Oil flow
Hydraulic
Motor
Oil out
Oil in
Pump &
Motor
Control panel
control device
control diagram
motor control
Motor
Control
Electronic controller
solid state devices
OP-Amps
rectifier
PLC
To other
processes
Incoming
power
Set point

Position Indicator with PID Control

